SR 108 MP 5.54 Unnamed Tributary to Skookum Creek (WDFW ID 990385): Preliminary Hydraulic Design Report

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Preliminary Hydraulic Design Report
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1 Introduction

To comply with United States et al. vs. Washington et al. No. C70-9213 Subproceeding No. 01-1 dated March 29, 2013 (a federal permanent injunction requiring the State of Washington to correct fish barriers in Water Resource Inventory Areas [WRIAs] 1–23), the Washington State Department of Transportation (WSDOT) is proposing a project to provide fish passage at the State Route (SR) 108 crossing of the Unnamed Tributary (UNT) to Skookum Creek at mile post (MP) 5.54. This existing structure on SR 108 has been identified as a fish barrier by the Washington Department of Fish and Wildlife (WDFW) and WSDOT Environmental Services Office (ESO) (site identifier [ID] 990385) and has an estimated 1,600 linear feet (LF) of habitat gain.

Per the injunction, and in order of preference, fish passage should be achieved by (1) avoiding the necessity for the roadway to cross the stream, (2) use of a full span bridge, or (3) use of the stream simulation methodology. WSDOT evaluated the crossing as defined in the injunction. Avoidance of the stream crossing was determined to not be viable given the location of the highway and the need to maintain this critical transportation corridor. WSDOT is proposing to replace the existing crossing structure with a structure designed using the bridge design methodology.

The crossing is located in unincorporated Mason County, 20 miles northwest of Olympia, Washington, in WRIA 14. The highway generally runs in an east–west direction at this location and is about 450 feet (ft) north of the confluence with Skookum Creek. The Unnamed Tributary generally flows from north to south beginning more than 2 miles upstream of the SR 108 crossing (see Figure 1 for the vicinity map).

The proposed project will replace the existing 6-foot-span, 72-foot-long concrete box culvert with a structure designed to accommodate a minimum hydraulic opening of 35 feet. The structure type is not being recommended by Headquarters Hydraulics and will be determined by others at future design phases. The proposed structure is designed to meet the requirements of the federal injunction using the confined bridge design methodology as described in the 2013 WDFW *Water Crossing Design Guidelines* (WCDG). This design also meets the requirements of the WSDOT *Hydraulics Manual* (WSDOT 2019).

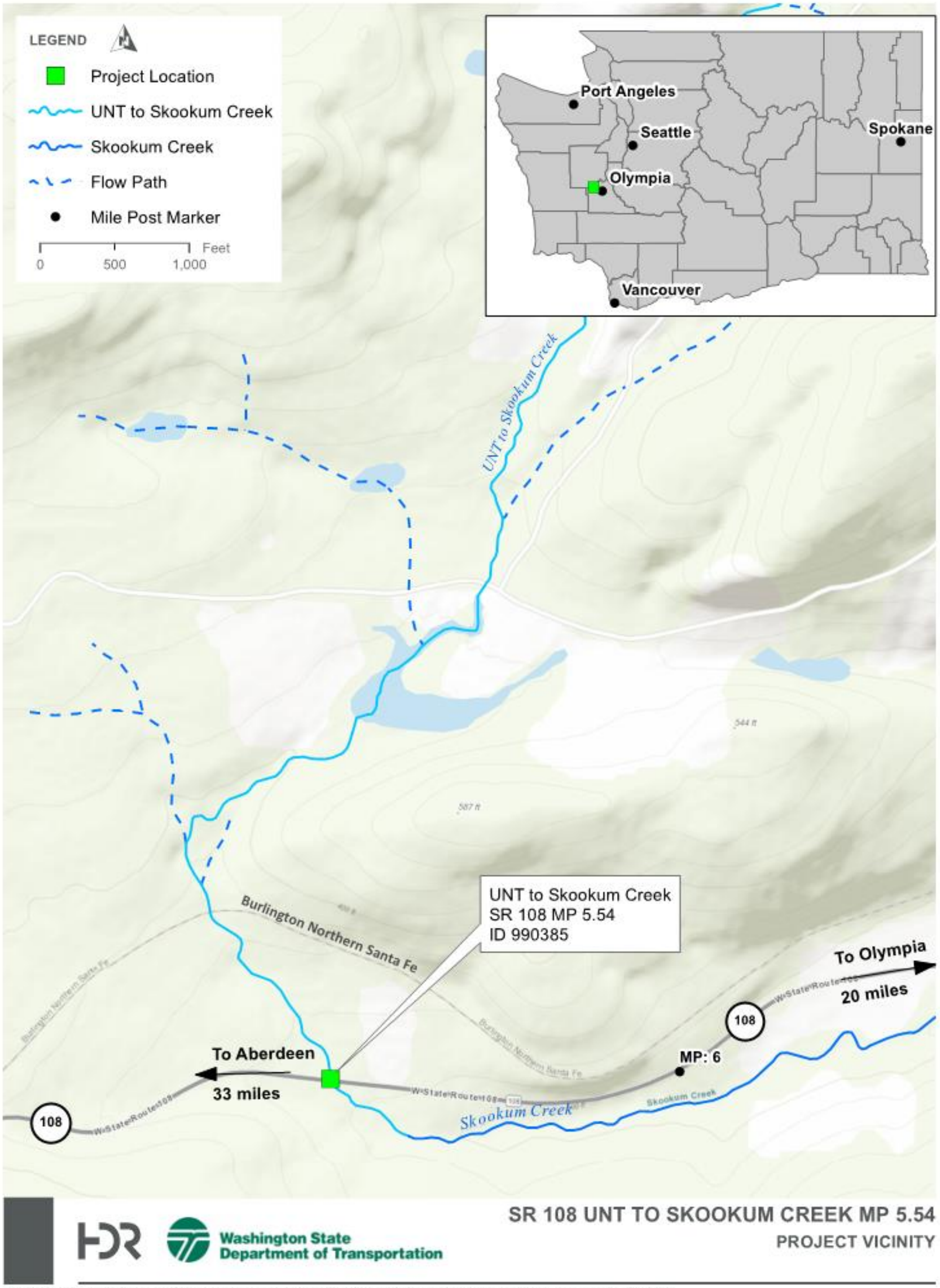

Figure 1: Vicinity map

2 Watershed and Site Assessment

This section presents a watershed and site assessment for the UNT to Skookum Creek at MP 5.54.

2.1 Watershed and Land Cover

The project watershed has a contributing drainage area to the site of 1,045 acres (1.6 square miles), and is north of the SR 108 crossing (see Figure 2). The basin was delineated using Arc Hydro and light detecting and ranging (LiDAR) data using the 2019 Olympics South dataset (Washington State Department of Natural Resources [DNR] LiDAR Portal). No major tributaries are present within this watershed, which lies in the Kamilche Valley with the major stream being Skookum Creek. Land cover for the watershed is generally forested, with some history of cleared land for either logging or agriculture.

Figure 2: Basin map

2.2 Geology and Soils

The surficial geology of the watershed is primarily glacial drift and Eocene crescent formations (Figure 3). As defined and summarized in the 7.5' quadrangle mapping by the Department of Natural Resources (Logan 2003), the following geologic units are present within the basin:

- **Qgt:** Pleistocene continental glacial till. This unit is an unsorted and highly compacted mixture of clay, silt, sand, and gravel deposited directly by glacier ice with very low permeability.
- **Ev(c):** Eocene Crescent Formation, volcanic rocks. Most commonly consists of breccias, columnar-jointed flows or sills, and glomerophyric dikes; filled lava tubes common in breccias.
- **Qgd:** Pleistocene continental glacial drift. This includes undifferentiated till and outwash sand and gravel containing granitic and metamorphic clasts.
- **Qgo:** Pleistocene continental glacial drift. Similar to Qga, a moderately to well-rounded and poorly to moderately sorted outwash sand and gravel of northern or mixed northern and Cascade source, that locally contains silt and clay; it also contains lacustrine deposits and ice-contact stratified drift.
- **Qgp:** Pleistocene continental glacial drift, pre-Fraser. This unit has undifferentiated till and outwash sand that contains characteristic granitic and metamorphic clasts.
- **Qa:** Quaternary alluvium. Consists of silt, sand, gravel, and peat deposited in streambeds, alluvial fans, and estuaries; includes some lacustrine and beach deposits.

The soil map units within the watershed are primarily gravelly loam and silty loam in areas of mild slopes (Figure 4) as mapped by the Natural Resources Conservation Service (NRCS) (Soil Survey Staff). The soil map units in the vicinity of the crossing are Cloquallum silt loam (CC) (upstream) and Juno loam (Jb) (downstream). The upper basin is composed of Delphi gravelly loam (De, Df), Grove gravelly sandy loam (Gk), and rough broken land (Rd, Re).

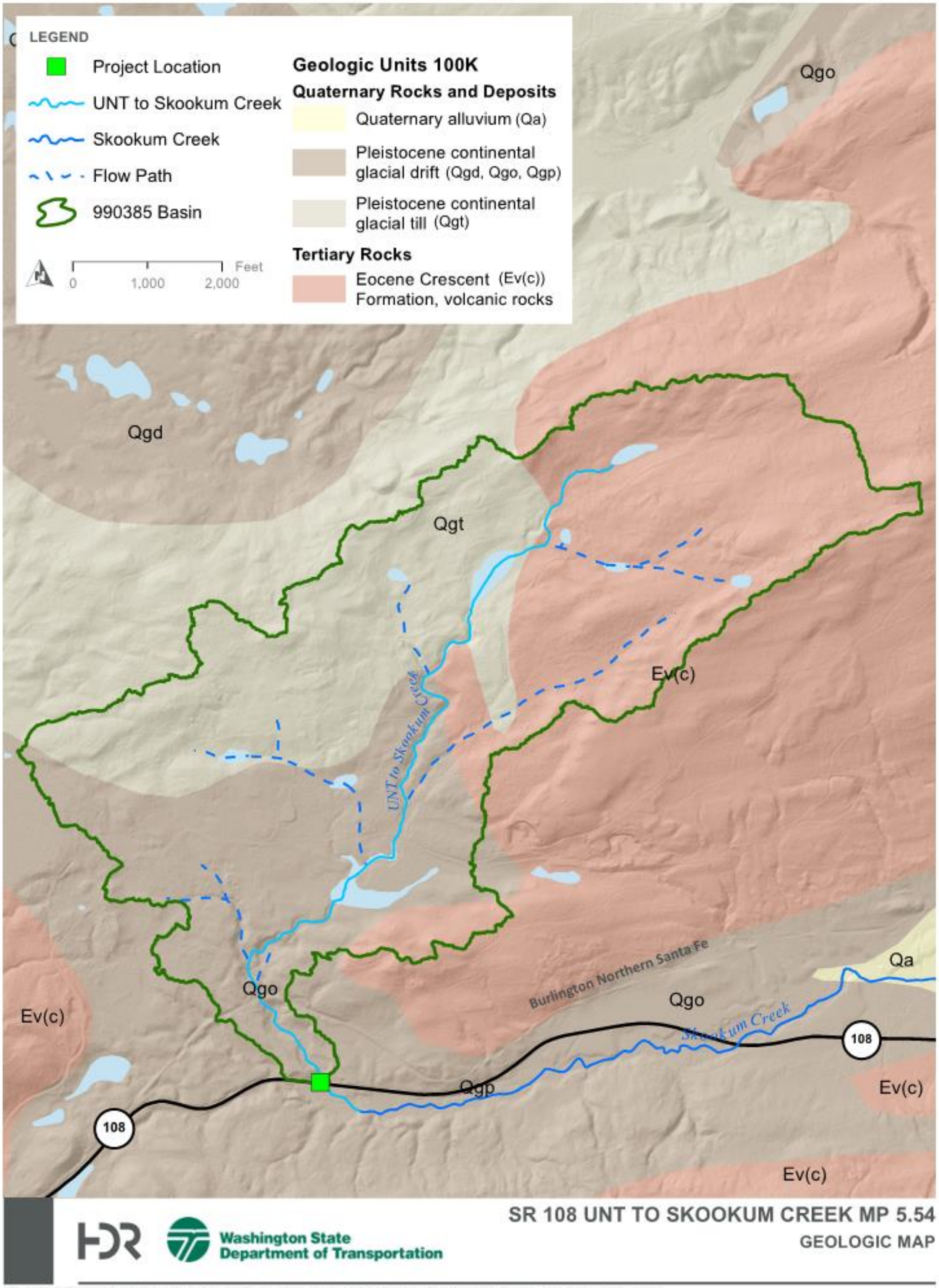

Figure 3: Geologic map (WA Division of Geology and Earth Resources)

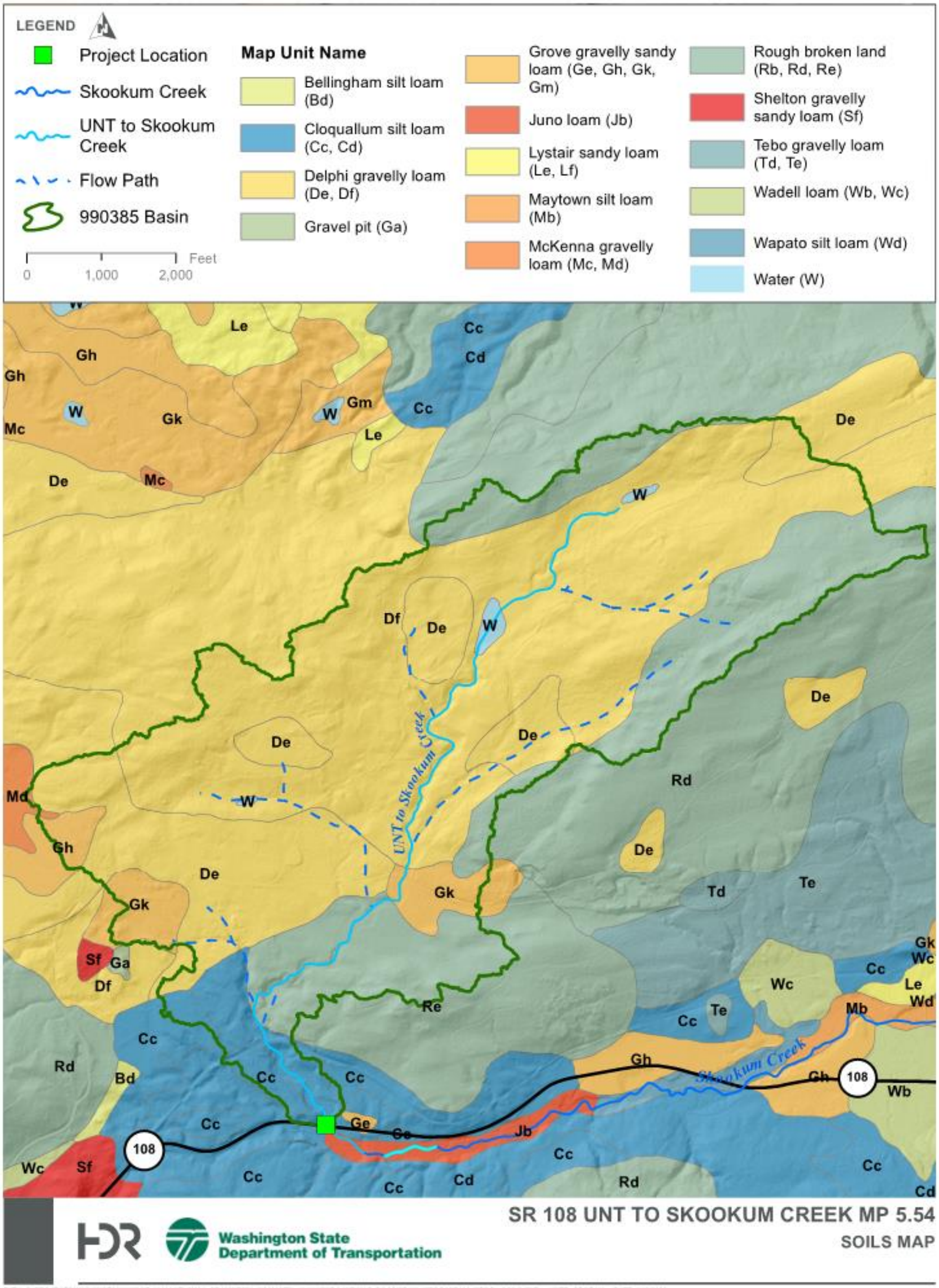

Figure 4: Soil map (Soil Survey Staff)

2.3 Floodplains

The project is not within a regulatory Special Flood Hazard Area, which is the 1 percent or greater annual chance of flooding in any given year. The existing SR 108 culvert is located in Zone X (unshaded) based on the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) 53045C0750E effective June 20, 2019. An unshaded Zone X represents areas of minimal flood hazard from the principal source of flooding in the area (Skookum Creek) and is determined to be outside the 0.2 percent annual chance floodplain. Downstream of the crossing, at the confluence with Skookum Creek, the area surrounding Skookum Creek is classified as Zone A. This area is subject to inundation by the 1 percent annual chance flood event as determined by approximate methods. A base flood elevation (BFE) has not been determined. See Figure 5.

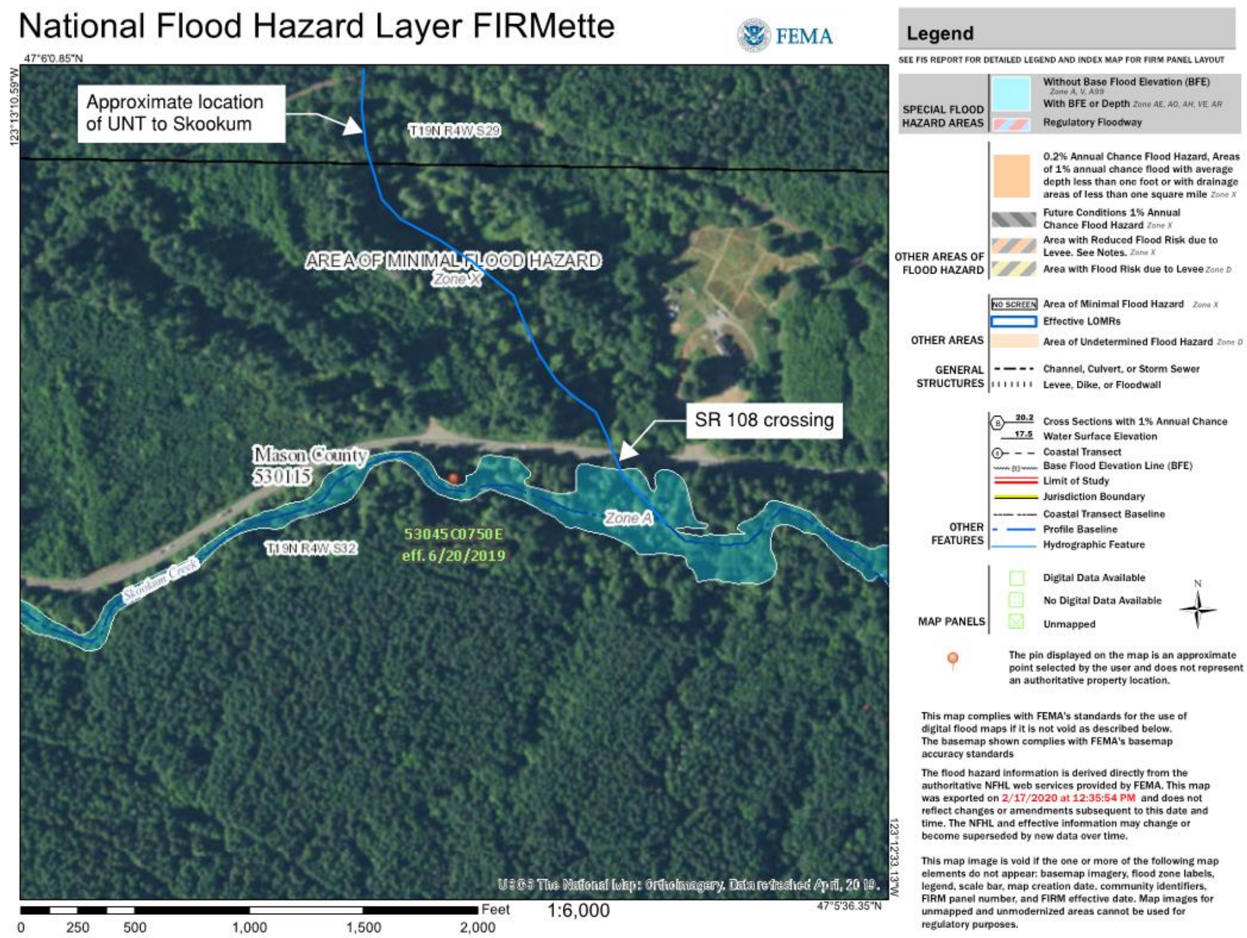

Figure 5: FEMA FIRMette for UNT to Skookum Creek

2.4 Site Description

The UNT to Skookum Creek at SR 108 MP 5.54 is listed as a 67 percent passable barrier within the WDFW Fish Passage database because of high velocity, which impairs fish ability to access upstream. It is currently not listed as a chronic environmental deficiency or failing structure. Maintenance history has been requested but has not yet been provided. The potential habitat gain that comes with replacing this fish barrier is 1,600 LF.

2.5 Fish Presence in the Project Area

The Unnamed Tributary to Skookum Creek within the project site supports the occurrence of fall-run coho salmon (*Oncorhynchus kisutch*), chum salmon (*Oncorhynchus keta*), winter-run steelhead (*Oncorhynchus mykiss*), and coastal cutthroat trout (*Oncorhynchus clarkii clarkia*) (Statewide Washington Integrated Fish Distribution [SWIFD] 2020; WDFW 2020a; WDFW 2020b; StreamNet 2020). Of these, winter steelhead that inhabit the watershed are part of the Puget Sound distinct population segment and are federally listed as threatened under the Endangered Species Act (ESA) of 1973. Besides salmonids, several additional fish species, including sculpin and lamprey, also inhabit the watershed. Table 1 provides a list of native fish potentially found in the Unnamed Tributary to Skookum Creek. Flows were shallow in the stream channel during the time of the site visit in January 2020 and no fish were observed.

Table 1: Native fish species potentially present within the project area

Species	Presence (Presumed, Modeled, or Documented)	Data Source	ESA Listing
Coho salmon (*Oncorhynchus kisutch*)	Documented	SWIFD	Not warranted
Chum salmon (*Oncorhynchus keta*)	Documented	SWIFD	Not warranted
Winter steelhead (*Oncorhynchus mykiss*)	Presumed	SWIFD	Federally threatened
Coastal cutthroat trout *(Oncorhynchus clarkii clarkia)*	Presumed	SWIFD	Not warranted

2.6 Wildlife Connectivity

WSDOT considered SR 108 in this vicinity a low wildlife priority route.

2.7 Site Assessment

The existing crossing at SR 108 MP 5.54 has potential to improve fish habitat by providing 1,600 LF of habitat gain with a fish-passable structure. The following sections describe the existing conditions of UNT to Skookum Creek as observed during multiple site visits conducted in early 2020.

2.7.1 *Data Collection*

HDR Engineering, Inc. (HDR) performed a site visit on January 21, 2020, to collect pertinent information to support the basis of design for the UNT to Skookum Creek at SR 108 MP 5.54 (site ID 990385). An additional site visit was conducted with stakeholders including representatives from WSDOT, WDFW, and the Squaxin Island Tribe. See Appendix A for the Field Report from the stakeholder site visit conducted on March 6, 2020. The Chehalis Tribe was not on site, but concurred with WDFW for bankfull width (BFW) measurements. Bankfull width measurements are summarized in Section 2.8.2.

A detailed topographic survey, conducted in March 2020 by 1 Alliance Geomatics, LLC (1 Alliance), encompasses what was seen during the site visit which was approximately 1,000 feet of channel. Roadway survey was collected a distance of 1,000 feet in both directions from the crossing.

The following paragraphs and Figure 7 through Figure 36 describe field observations of the UNT from upstream to the downstream confluence with Skookum Creek. Figure 6 shows a plan view of the Tributary upstream and downstream of the crossing, sketched from observations made during the site visit. It highlights features in the Tributary such as large woody material (LWM), planform shape, cross-sectional shape, and confluences.

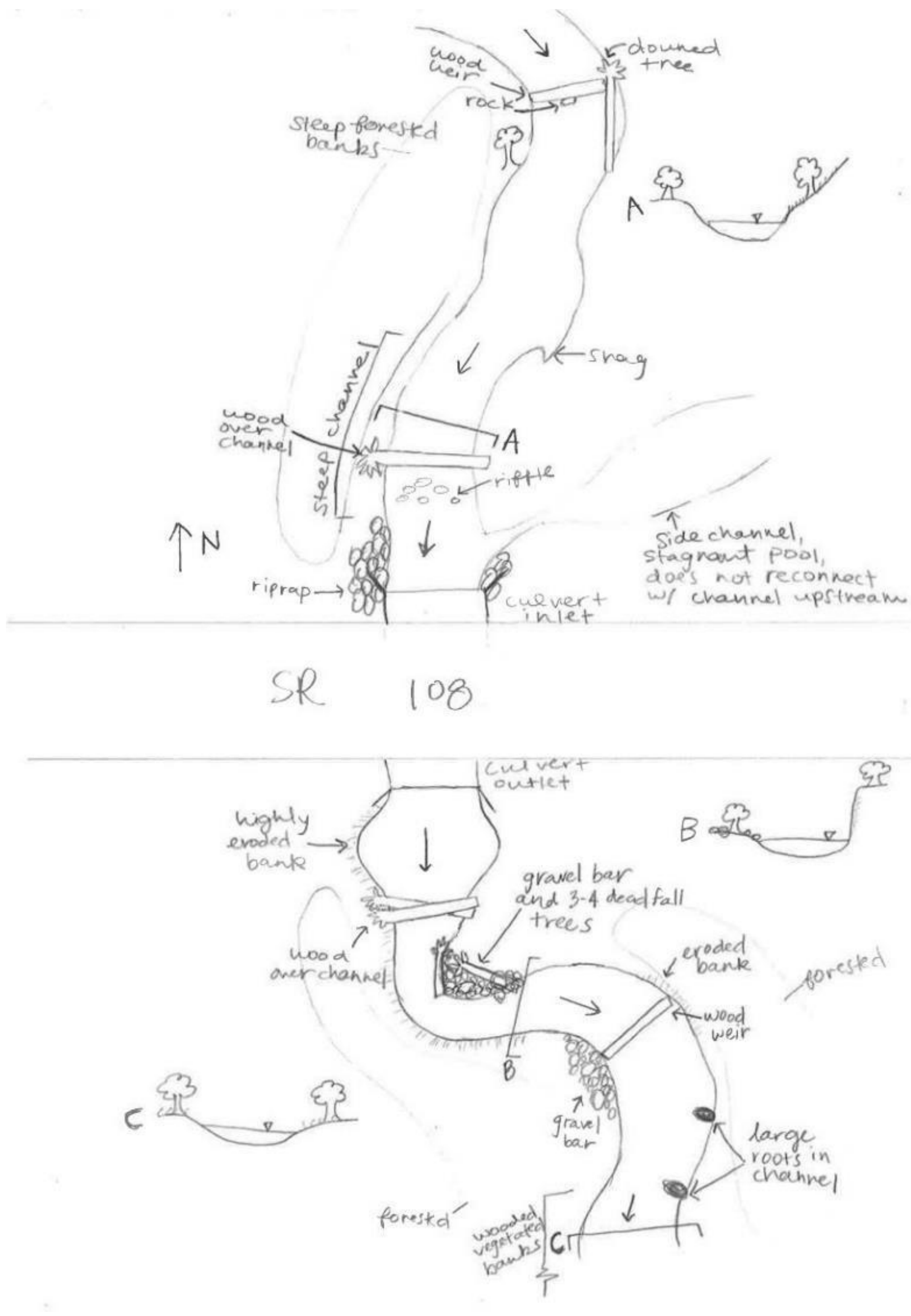

Figure 6: Plan view and cross sections of upstream and downstream reaches of the crossing (not to scale)

The upstream reach of the UNT has consistently vegetated banks with wooded floodplains. LWM is present throughout the upper reach and some riffles were also observed. The reach substrate is consistently gravel and small cobbles. Beginning approximately 300 feet upstream of the crossing, the UNT passes through riffles before taking a rough 75-degree right turn over a fallen wood weir spanning the entire channel, creating a 2-foot hydraulic drop (see Figure 8).

Figure 7: Looking upstream from the wood weir

Figure 8: Upstream and downstream of the wood weir

Directly downstream of the drop, the right banks are slightly undercut and there is woody material on the left banks as the channel takes a slight right turn. Banks in this reach are 2 to 3 feet tall.

Figure 9: Downstream of the rock and wood weir

Downstream of the bend, the channel remains fairly straight in a run, with the thalweg generally keeping to the left side of the channel. Three bankfull widths were taken spaced 30 feet apart at this location, beginning 50 feet downstream of the wood weir. The average bankfull width was 20.8 feet. Within the bankfull width area the largest material of 21.3 inches (in) (542 millimeters [mm]) was found (see Figure 41).

Figure 10: Straight run looking upstream

Figure 11: Bankfull width measurement being taken, looking downstream

About 30 feet downstream of the bankfull width area, the channel takes a slight bend to the right. A small overbank side channel begins at this location, with some overbank flow at higher flows entering the side channel that reenters just upstream of the culvert.

Figure 12: Looking downstream at left bank overbank side channel beginning

Figure 13: Closer look at left bank overbank side channel beginning

Continuing down the mainstem of the Tributary, the left banks are about 2 feet high and the right banks are 3 feet high with a small gravel bar in the middle of the channel. A downed tree spans the channel banks 3 feet above the stream that marks a differing channel slope. Upstream the channel is fairly shallow, and downstream the channel is much steeper traveling over a short cascade leading into the culvert. The cascade contains angular material that either was placed or fell into the channel from the right bank.

Figure 14: Upstream of the fallen tree, looking downstream

Figure 15: Downstream of the fallen tree, looking upstream

A side channel begins approximately 150 feet upstream of its confluence with the Unnamed Tributary just upstream of the culvert inlet. It has no upstream connection to the Tributary. It meanders 30 to 50 feet to the left of the Tributary until stagnating at a large pool directly upstream of the confluence.

Figure 16: Looking downstream from atop the left bank

Figure 17: Directly upstream of the culvert inlet, looking to the left bank at the stagnant pool

The channel is steep with angular material within the channel as it enters the culvert and heavy riprap on the 7-foot-high right banks. The side channel outfalls to the left of the culvert inlet. The 6-foot-span concrete box culvert has an exposed bottom with 45-degree wingwalls.

Figure 18: Looking downstream at the culvert inlet

Figure 19: Looking downstream at the culvert inlet

The downstream reach remains fairly vegetated with woody material providing habitat within the stream. The channel substrate is consistently gravel and small cobbles. The Tributary meanders roughly 450 feet until reaching the confluence with Skookum Creek.

The culvert outlet has concrete wingwalls with 45-degree angles. The bottom is not exposed and natural material is present within the downstream end of the culvert.

Figure 20: Looking upstream at the culvert outlet

Figure 21: Looking upstream through the culvert

At the culvert outlet there is a larger pool. Downstream of the pool there are several deadfall trees from an eroded right bank. There is a riffle at the downstream end of the culvert outlet pool as flow transitions under the downed trees and flow is directed toward the right bank.

Figure 22: View from the left bank at the culvert outlet looking downstream

Figure 23: Looking downstream at the fallen trees

Continuing downstream there is woody material within the stream that has directed flow into the right bank and caused erosion along the right bank. The wood has helped accumulate smaller wood, sediment, gravel, and sandy substrate. This obstruction has confined the channel to the right at a 90-degree bend, and has created highly eroded right banks that sit roughly 5 feet tall.

Figure 24: Looking upstream from the debris-filled left bank

Figure 25: Looking upstream at the eroded right bank and left bank gravel bar

Figure 26: Looking upstream at the blockage and confined channel

Immediately downstream of the blockage, the channel straightens for about 15 feet and takes a 90-degree bend to the right. As the right bank declines from 5 feet high to approximately 1 to 2 feet with a right bank point bar, the left banks increase from a gravel bar to about 3 to 4 feet high with many roots extending into the channel. Throughout the channel the banks are a sandy material.

Figure 27: Looking downstream at right 90-degree turn

Figure 28: Looking upstream at the bend and root-covered left banks

Downstream of the bend the channel meanders slightly to the left. From this point on, the banks remain vegetated and are not as eroded compared to the immediate upstream reach. A wood weir spanning the channel creates a 1-foot hydraulic drop as the channel bends to the right. Downstream of the weir woody material is present on both the left and right sides of the channel.

Figure 29: From the right bank, looking at the wood weir

Figure 30: From the left bank, looking downstream

Figure 31: Looking upstream from the left bank

The Tributary continues along a straight path for approximately 50 to 60 feet until reaching a log jam that spans almost the whole channel. It consists of one or two downed trees along with smaller mobile woody material that has accumulated on the jam. It forces the Tributary to cross near the right bank, creating a gravel bar in the middle of the channel immediately downstream of the jam.

Figure 32: Looking downstream at the log jam

Figure 33: Looking upstream from the gravel bar at the log jam

Figure 34: Material on the gravel bar

The Tributary continues roughly 50 feet to the confluence with Skookum Creek, which joins the mainstem from the left bank. The Tributary is almost double the bankfull width of Skookum Creek.

Approximately 20 feet downstream of the confluence another log jam that has accumulated woody material spans the entire channel.

Figure 35: Looking upstream at the confluence of Skookum Creek and the tributary just before the log jam

Figure 36: Looking downstream at the confluence of the Tributary and Skookum Creek and the log jam

Six bankfull widths were taken beginning 20 feet upstream of the confluence and spaced 20 feet apart moving upstream (both downstream and upstream of the initial log jam). The average bankfull width for this downstream reach was 22.2 feet. Bankfull measurements are summarized in Section 2.8.2. Figure 37 below shows a bankfull width measurement being taken.

Figure 37: Bankfull width measurement being taken, looking upstream

2.7.2 *Existing Conditions*

The existing 6-foot-span, 72-foot-long concrete box culvert is at an adverse slope of -0.2 percent according to the March 2020 survey. The structure is aligned perpendicular to SR 108 with no skew. Upstream of the structure the stream is fairly steep with angular material in the channel and heavy riprap on the right banks. A small side channel outfalls to the left of the culvert entrance. At the culvert outlet deadfall trees have created eroded right and left banks.

A small culvert approximately 250 feet east of the crossing serves as an overflow culvert for the UNT during high flows based on the existing hydraulic model. This 18-inch-diameter concrete culvert is perpendicular to the roadway with a slope of 0.3 percent. When used, the water travels roughly 100 feet to the south through a defined channel before joining back in with the UNT.

No obvious signs of maintenance activity were observed at the time of the site visits.

This crossing, listed in WDFW's database as a significant reach, currently limits fish spawning and rearing habitat by 8,700 square feet (SF) and 16,500 SF, respectively. By removing and replacing the crossing with a fish passage structure the potential habitat gain is 1,600 LF.

2.7.3 *Fish Habitat Character and Quality*

Skookum Creek is a significant watershed in south Puget Sound, with numerous tributaries providing habitat for salmonids. Land use is predominantly timber production at higher elevations with livestock and pasture/hayfields in the mid and lower valley. The Skookum Creek watershed provides spawning and rearing habitat for coho, chum, steelhead, and cutthroat trout throughout the mainstem and accessible reaches of its tributaries. These anadromous species, which are part of Puget Sound stocks, access Skookum Creek through Little Skookum Inlet off Totten Inlet in south Puget Sound. In addition to fish passage barriers in the upper watershed, the most significant biological impairments are habitat diversity and quantity, sediment load/transport, and summer water temperatures.

The Unnamed Tributary is a left bank tributary to Skookum Creek that provides spawning, rearing, and migratory habitat for salmonids and other fish species. The confluence with Skookum Creek is located approximately 450 feet downstream of the culvert exit. Skookum Creek continues for approximately 7.7 miles to where it enters Little Skookum Inlet.

Upstream of the SR 108 crossing, the Unnamed Tributary flows through a mature mixed forested area comprising primarily fir, alder, and bigleaf maple, with some large cedars. There is a dense shrub understory with native and non-native species including salmonberry, willows (Salix spp.), vine maple, and Himalayan blackberry. The mature forest and shrub cover provide good shading, nutrient inputs, and some potential LWM recruitment.

The stream channel is predominantly riffle habitat with a few small cascades and rapids. The substrate is dominated by gravel and cobble throughout the reach. The lower reach next to the culvert inlet has some riprap and spall in a steeper gradient than farther upstream. Pool habitat is lacking in the upstream reach. Overall, the stream channel in the upstream study reach is fairly uniform and instream habitat complexity is low. Habitat in this reach is predominantly suited to seasonal migration and some rearing, particularly during higher flow periods. There is limited potential spawning habitat, and pool-riffle complexes are lacking, but small amounts of LWM provide some instream habitat complexity. Five pieces of LWM observed in the upstream reach consisted primarily of conifers 12 to 24 inches in diameter. Most of these spanned the bankfull channel (Figure 14 above) and provide limited instream habitat function. A log across the channel within the streambed at the upstream end of the survey has created a 2-foot-high hydraulic drop (Figure 8 above) that is impassable to juvenile salmonids moving upstream under most flow conditions. During higher or flood flows this drop may be passable for juveniles to disperse upstream.

An off-channel wetland and floodplain habitat on the left bank provides potential off-channel rearing habitat when inundated during periods of higher flow.

Downstream of the SR 108 culvert crossing, the Unnamed Tributary flows through a mixed canopy of mostly deciduous trees containing alder (*Alnus rubra*) and bigleaf maple (*Acer macrophyllum*), with some conifers including Douglas fir (*Pseudotsuga menziesii*) and western red cedar (*Thuja plicata*). The understory comprises native and non-native species including salmonberry (*Rubus spectabilis*), vine maple (*Acer circinatum*), sword fern (*Polystichum munitum*), and some Himalayan blackberry (*Rubus armeniacus*). The mature forest and shrub cover provide good shading, nutrient inputs, and potential LWM recruitment. LWM is important in western Washington streams because it provides cover for fish and contributes to stream complexity, which is beneficial to salmonids. In the downstream reach, 17 pieces of LWM were observed that included some conifers, as well as two log jams each consisting of four to eight large logs with branches and some woody debris, as well as root wads. Many of these provided good instream cover and habitat complexity in the reach. A large debris jam comprising large-diameter logs and branches formed a deep pool with good cover providing a good rearing and resting pool. Overall, this reach has functionally abundant LWM comprising both conifers and alders, and good LWM recruitment potential from the surrounding mature forested riparian corridor.

The stream channel in the downstream reach contains predominantly riffle habitat with some shallow pools located at log jams and along scoured sections of bank. Pools were generally small in size relative to the channel, but provide good cover for rearing and resting. The streambed substrate comprises fines, small gravels, and cobbles, with gravel and cobble being dominant. Mid-channel sediment bars have formed throughout the reach. Some areas of gravel, particularly at pool tailouts, provide potential spawning habitat for the smaller species of salmonids such as coho and cutthroat trout.

2.8 Geomorphology

This section presents a description of the geomorphology of the UNT to Skookum Creek at MP 5.54.

2.8.1 *Reference Reach Selection*

A section of stream approximately 200 feet upstream of the culvert (see Figure 38 and Figure 39) was identified as the reference reach because it is most representative of a naturally occurring channel, with the least amount of anthropogenic influences. This reach has an approximate average channel gradient of 2.1 percent. Results of a pebble count conducted within the reference reach are summarized in Section 2.8.3.

Figure 38: Photo of reference reach, looking upstream; the reference reach is at the bottom of the photo

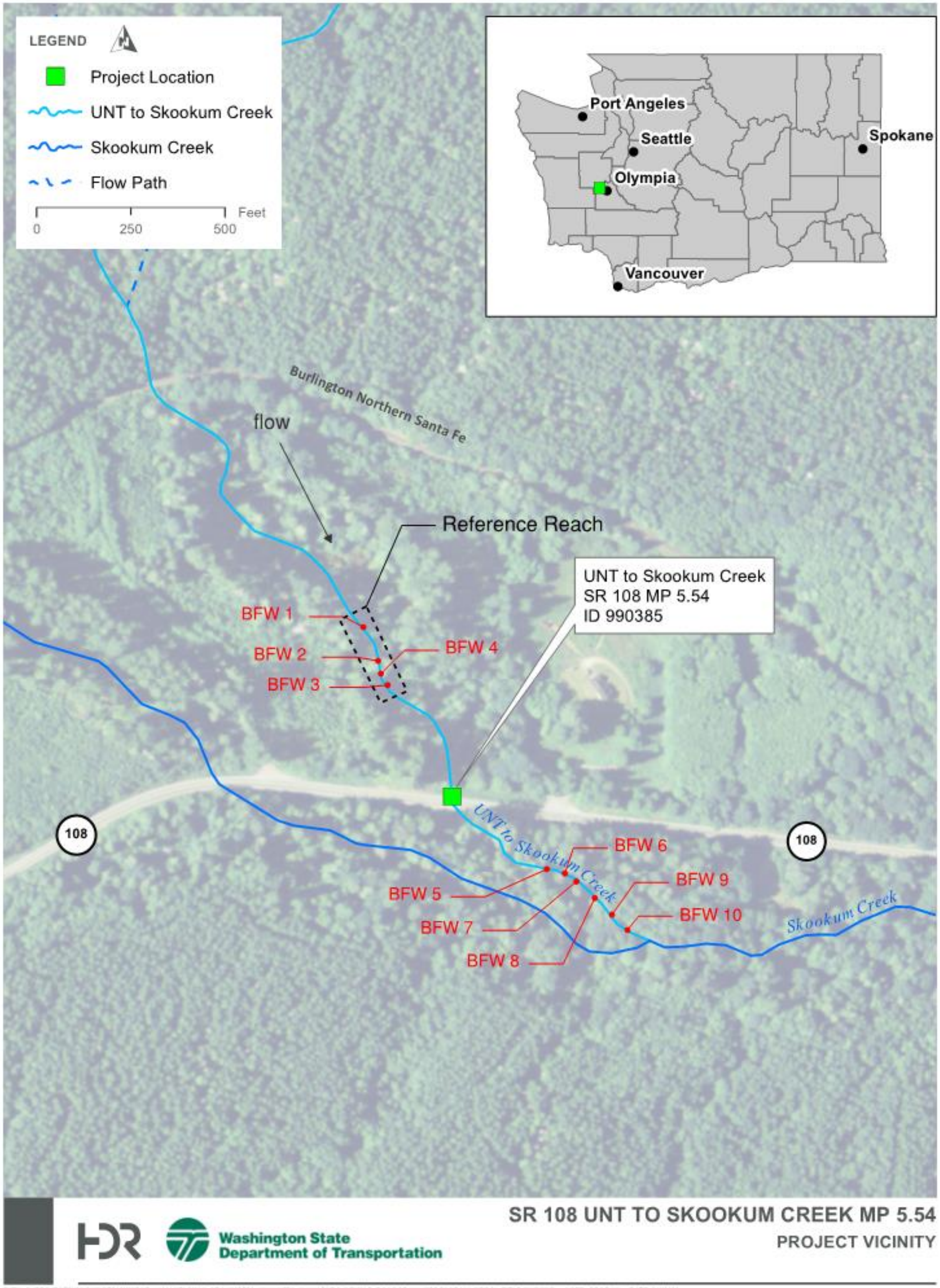

Figure 39: Reference reach

2.8.2 *Channel Geometry*

The channel planform meanders with a medium amount of sinuosity, both upstream and downstream of the crossing, confined upstream on the right bank by a steep valley wall and on the left bank by a shallow floodplain. Downstream the channel meanders through shallower floodplains away from the valley walls. The channel cross section is wide with the thalweg primarily in the middle of the channel besides at bends. It is fairly shallow across with some occasional gravel bars that accumulate on the banks and in the middle of the channel.

Bankfull width measurements were collected upstream and downstream of the crossing. Eight bankfull widths were taken, ranging from 16 to 26 feet. During the stakeholder site visit on March 6, 2020, with WDFW, WSDOT, and the Squaxin Island Tribe representative, previously measured bankfull widths were evaluated for concurrence and two additional bankfull widths were added, for ten total measurements. The Chehalis Tribe was not on site but concurred with WDFW's ruling. Table 2 summarizes bankfull measurements that were used to determine the design bankfull width. Two measured bankfull widths were not used as they were not within representative areas of the stream. The agreed-upon bankfull widths resulted in a design average bankfull width of 23.5 feet. The slope of the reference reach is 2.1 percent, which is being compared to the proposed design. Approximate locations of bankfull widths and the reference reach are identified in Figure 39 above. See Figure 11 and Figure 37 above for photos of a representative bankfull width section upstream and downstream, respectively.

For comparison, a bankfull width was calculated based on the WCDG (2013) regression equation for high-gradient, coarse-bedded streams in western Washington. Using the basin area (1.63 square miles) and average mean annual precipitation of 85 inches/year (PRISM 2004) the regression equation estimates a bankfull width of 17.8 feet. This bankfull width was not used to determine a design bankfull width, but is provided for informational purposes.

Table 2: Bankfull width measurements

BFW #	Width (ft)	Included in Design Average	Concurrence Notes
Upstream			
1	16.0 ft	No	Stakeholder concurred on 3/6/2020
2	21.0 ft	Yes	Stakeholder concurred on 3/6/2020
3	25.5 ft	Yes	Stakeholder concurred on 3/6/2020
4	29.0 ft	Yes	Stakeholder added on 3/6/2020
Downstream			
5	19.3 ft	No	Stakeholder removed on 3/6/2020
6	20.0 ft	Yes	Stakeholder added on 3/6/2020
7	23.0 ft	Yes	Stakeholder concurred on 3/6/2020
8	21.5 ft	Yes	Stakeholder concurred on 3/6/2020
9	21.0 ft	Yes	Stakeholder concurred on 3/6/2020
10	26.0 ft	Yes	Stakeholder concurred on 3/6/2020
Design average	23.5 ft		

The width:depth ratio is the bankfull width divided by the mean depth of the bankfull channel. For the 100-year event, the width:depth ratio is 11 within the reference reach. A series of cross sections is presented in Figure 40; Station (STA) 8+52 is located within the reference reach.

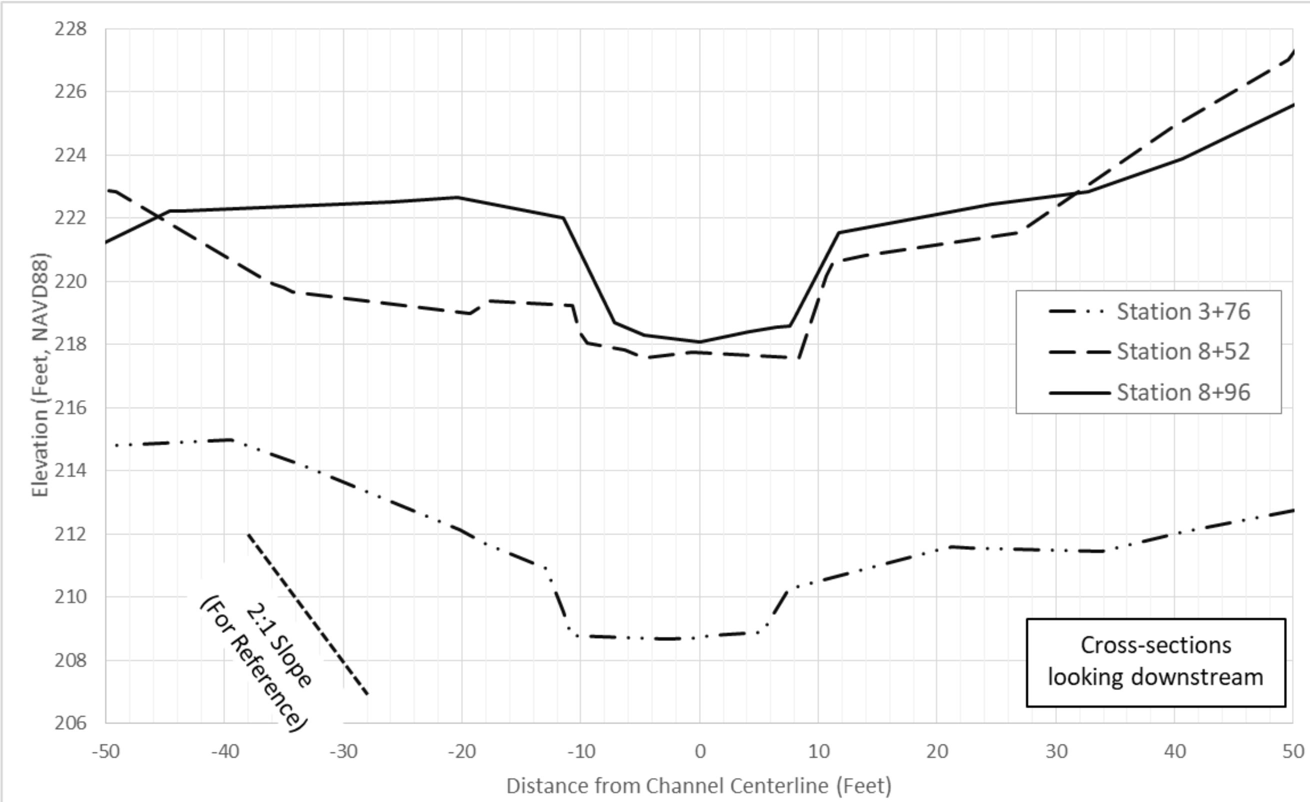

Figure 40: Existing cross-section examples

2.8.3 *Sediment*

During the January site visit, a Wolman pebble count was conducted upstream and downstream of the SR 108 culvert crossing. Each pebble count location consisted of sampling more than 300 streambed particles. The pebble counts were taken at the same location where bankfull width measurements were taken (see Figure 39 above). Table 3 provides a summary of pebble count data. The pebble counts were located in areas beyond the influence of the culvert both upstream and downstream. The results of the pebble count indicated that the substrate was composed primarily of fine to very coarse gravel and small cobbles in both reaches. The median particle size (D_{50}) was estimated to be 1.2 inches in diameter. The largest sediment size in the upstream pebble count reach observed was 1.8 feet in diameter (see Figure 41 below). Figure 42 presents the sediment size distribution for the site.

Figure 41: Largest material observed

Table 3: Sediment properties of project crossing

Sediment Size	Upstream Diameter (in)	Downstream Diameter (in)	Cumulative Diameter (in)
$\mathbf{D_{16}}$	0.4	0.5	0.4
$\mathbf{D_{50}}$	1.3	1.2	1.2
$\mathbf{D_{84}}$	4.0	2.2	2.8
$\mathbf{D_{95}}$	7.8	3.1	5.0
$\mathbf{D_{100}}$	21.3	7.1	21.3

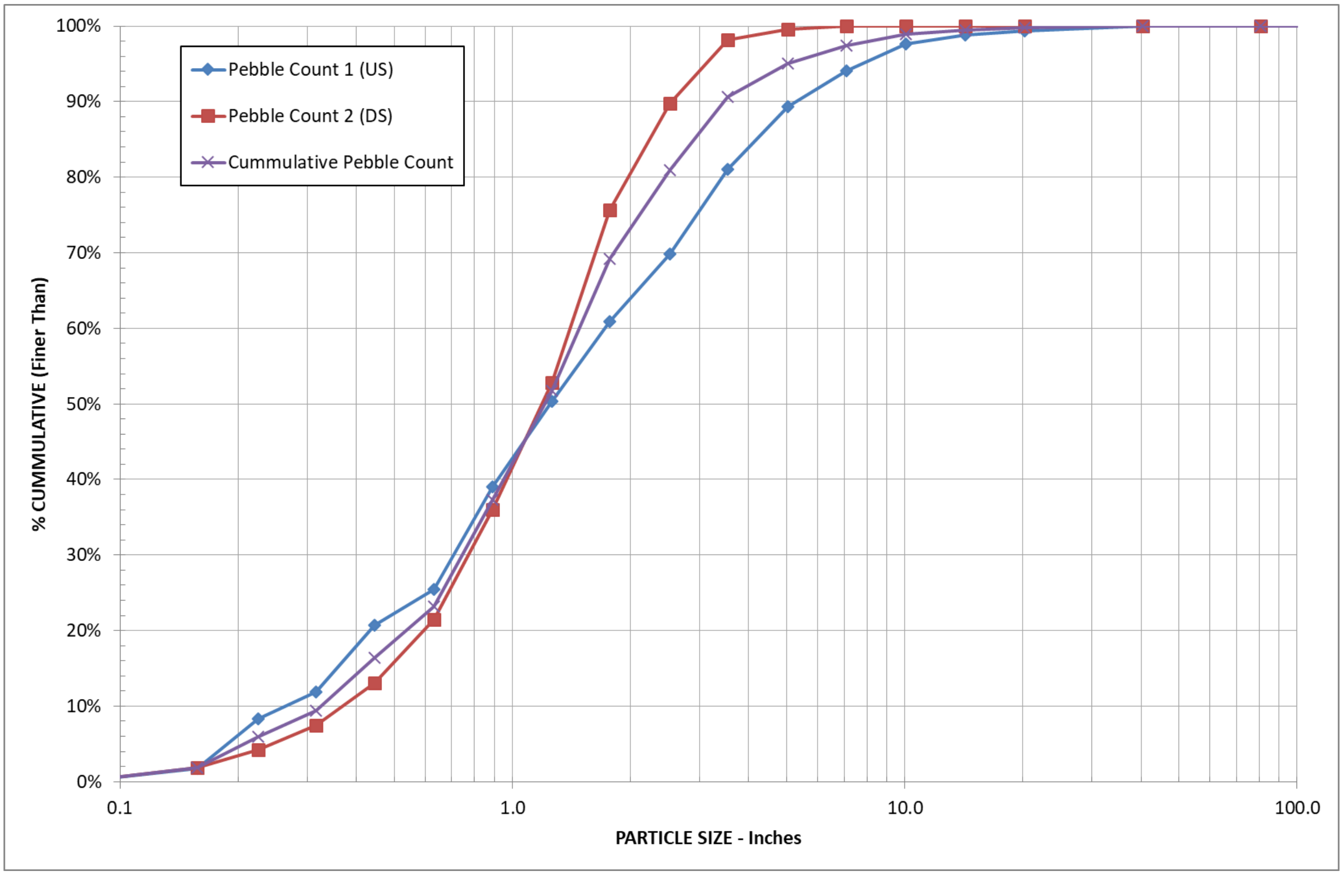

Figure 42: Sediment size distribution

2.8.4 *Vertical Channel Stability*

A long channel profile was developed from 2020 survey data and 2019 Olympics South LiDAR data (Washington DNR LiDAR Portal 2020). The long channel profile (Figure 43) describes slopes approximately 800 feet upstream and 1,600 feet downstream (including Skookum Creek) from the project culvert and includes major landmarks along the Tributary.

At the farthest upstream point of the survey the channel meanders slightly, but is defined by vegetated floodplains within the Kamilche Valley. Outside of the upstream survey extents the slope is approximately 2.1 percent. Within the survey limits, the upstream ranges from 2.1 to 3.5 percent with a steep slope into the culvert. At Station 18+90 on the long channel profile a natural wood weir creates a 2-foot drop.

Downstream, the channel meanders between vegetated floodplains with some eroded banks around sharp curves. Within the survey extents, the stream is at a 1.5 to 1.9 percent slope. At Station 13+25 there is another natural wood weir with a 1-foot drop. Skookum Creek comes in on the right bank at Station 11+50, and a log jam at Station 11+25 creates a 2-foot elevation drop. Past the survey extents the stream grade remains fairly consistent at a slope of approximately 1.3 percent.

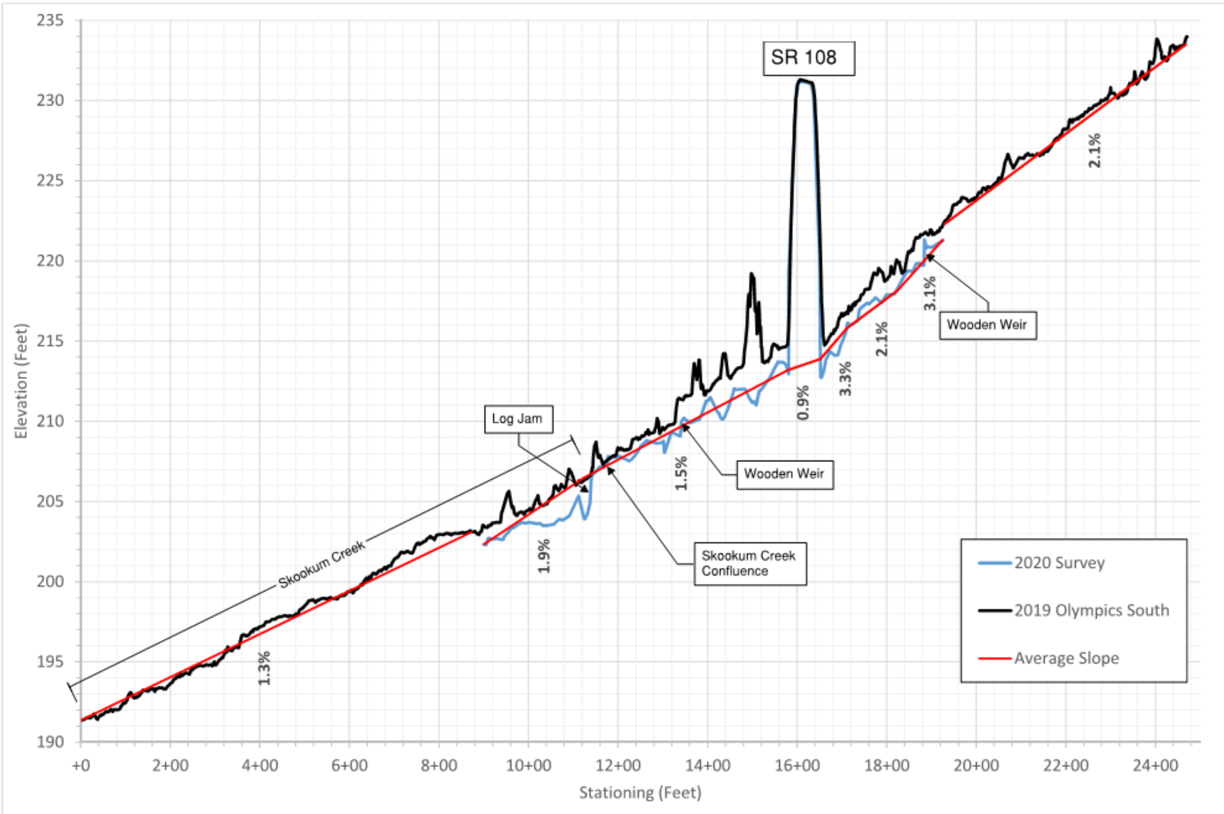

Figure 43: Watershed-scale longitudinal profile

During the site visit no excessive sediment deposits were observed. Minimal risk of aggradation and degradation is expected within this reach; there is no discontinuity within the long channel profile and no measurable aggradation or degradation was observed. Aggradation and degradation are expected to be less than 1 foot for both.

2.8.5 *Channel Migration*

The channel has the opportunity to migrate slightly on the upstream side coming into the culvert based on lower floodplains on the left bank and an existing side channel. Similarly, downstream has a tall right bank that limits migration and lower vegetated left bank. Signs of localized bank erosion were observed, primarily downstream, where the channel has widened slightly. This appeared to have typically occurred at sharp bends or where large wood had fallen into the channel.

Using historical imagery from Google Earth and USGS topography maps, the channel does not seem to have migrated from its current location from the 1950s to today.

2.8.6 *Riparian Conditions, Large Wood, and Other Habitat Features*

The riparian corridor surrounding the project area is fairly dense mature forest canopy with a mixture of young and older trees. In general the UNT and Skookum Creek lie within the Kamilche Valley, a forested area with some agriculture land throughout. LWM is naturally present throughout the stream reach, with wood weirs, log jams, and naturally occurring root wads in the channel (see Section 2.7.3). This LWM has created pools, forced flows to sides of the channel, and in a couple of locations created natural weir structures. In particular in the downstream reach, LWM provides instream habitat complexity and stream stability. There were 17 pieces of LWM and two large log jams within the downstream reach. The downstream reach begins with multiple deadfall trees that were recruited from the bank that span the channel. Three or four trees within the stream have directed flow into the right bank and eroded the bank. There is a natural log weir spanning the channel and two large log jams.

Within the upstream reach there are five pieces of LWM, including one acting as a weir, and an approximately 1-foot-diameter downed log parallel to the left bank near the weir. Throughout the upstream and downstream reaches, the mature forest riparian areas provide good shading, nutrient inputs, and potential LWM recruitment.

This reach has a high potential of recruiting more woody material because of stream size and the existing forested area.

3 Hydrology and Peak Flow Estimates

Hydrologic calculations were performed for three separate basins: (1) SR 108 MP 5.54 UNT basin, (2) the Skookum Creek mainstem above the UNT, and (3) an additional UNT on the right bank of the Skookum Creek mainstem, approximately 80 feet upstream of the confluence with the UNT and Skookum Creek. See Figure 44 below for locations of the boundary conditions; note there are three inflow locations.

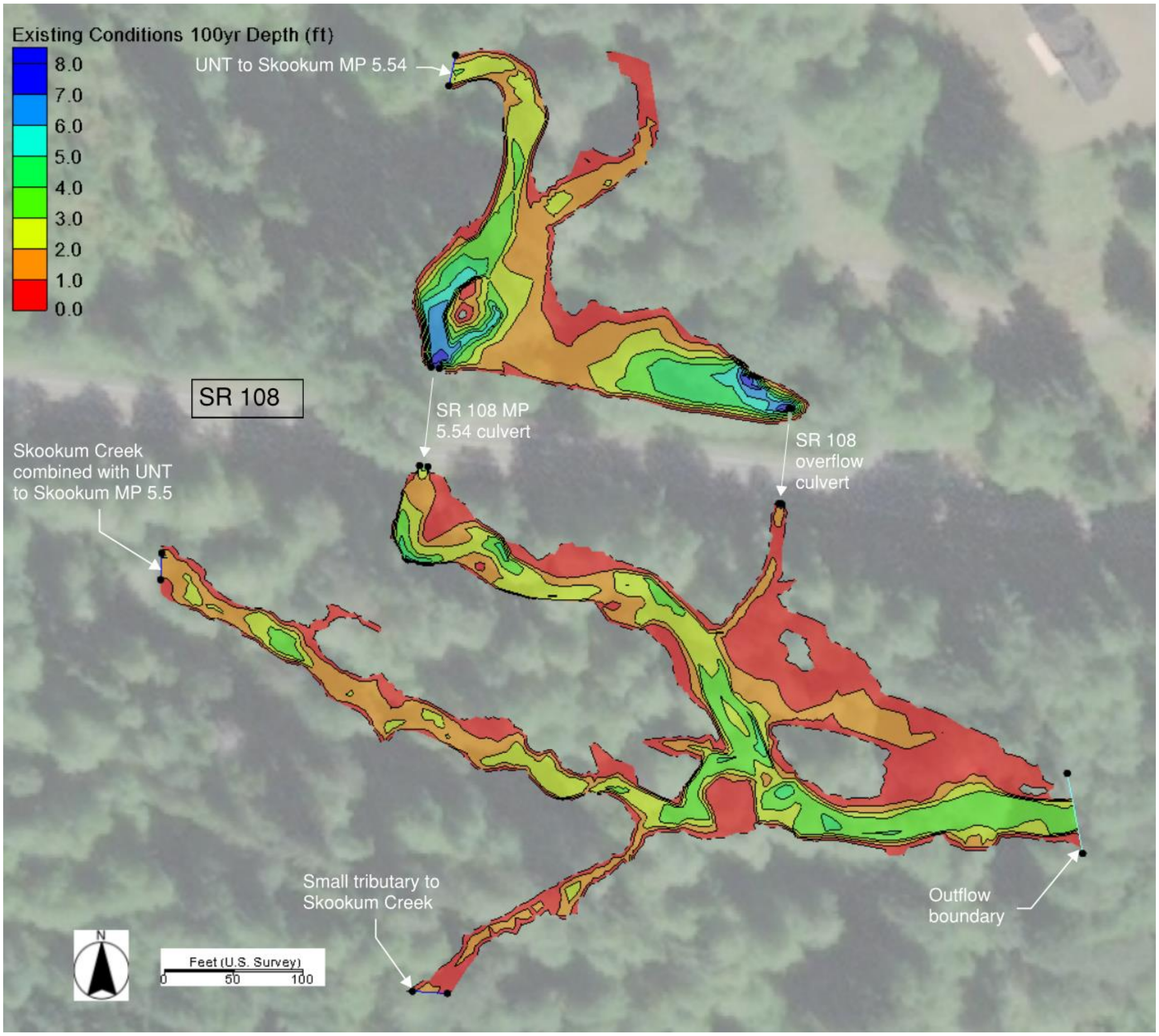

Figure 44: Hydraulic model boundary conditions

The Unnamed Tributary to Skookum Creek is within an ungaged basin, with no long-term historical flow data available. No hydrologic studies, models, or reports were found that summarized peak flows in the basin, and no gaged basin with similar characteristics was located. As a result, USGS regression equations (Mastin et al. 2016) for Region 3 were used to estimate peak flows at the SR 108 crossing. Inputs to the regression equation included basin size and mean annual precipitation. The UNT has a basin area of 1.63 square miles and a mean annual precipitation within the basin of 85 inches (PRISM 2019). The basin was delineated from LiDAR data acquired from the Washington DNR LiDAR Portal (2019 Olympics South) using Arc Hydro. The 2-year peak flow was estimated to be 109 cfs and the 100-year flow was estimated to be 326 cfs. Average standard error varied from 41.2 to 50.6 percent. Standard error was not applied to the flows used in the hydraulic modeling. Table 4 shows the calculated peak flows for the Unnamed Tributary to Skookum Creek at SR 108. For more information on the 2080 predicted 100-year flow determination see Section 7.2.

The hydrology for the mainstem of Skookum Creek has been previously summarized in the Preliminary Hydraulic Design (PHD) Report for the SR 108 MP 5.50 and is summarized in Table 4. These values were also estimated using the USGS regression equations.

A small tributary joins with Skookum Creek 80 feet upstream of the confluence with the Unnamed Tributary to Skookum Creek from MP 5.54. This small basin does not cross any roadways. StreamStats was used to delineate the basin and obtain peak flows. See Table 4 for flow rates used in the hydraulic model.

Table 4: Peak flows for the Unnamed Tributary to Skookum Creek at SR 108

Mean Recurrence Interval (MRI) (years)	UNT to Skookum Creek (cfs)	Skookum Creek (cfs)	Small Tributary to Skookum Creek (cfs)	Regression Standard Error (percent)
2	109	64.3	17.2	50.6
10	205	121.5	32.6	48.9
25	254	149.4	40.1	46.9
50	288	169.3	45.4	45.5
100	326	191.1	51.2	44.7
500	413	240.0	64.3	41.2
2080 predicted 100	360.6	211.4	56.6	NA

4 Hydraulic Analysis and Design

The hydraulic analysis of the existing and proposed SR 108 UNT to Skookum Creek crossing was performed using the U.S. Bureau of Reclamation's SRH-2D Version 3.2.4 computer program, a two-dimensional (2D) hydraulic and sediment transport numerical model. Pre- and post-processing for this model was completed using SMS Version 13.0.12.

Three scenarios were analyzed for determining stream characteristics for UNT to Skookum Creek with the SRH-2D models: (1) existing conditions with the 6-foot-span concrete box culvert, (2) natural conditions with the roadway embankment removed and the channel graded, and (3) future conditions with the proposed 35-foot hydraulic opening.

4.1 Model Development

This section describes the development of the model used for the hydraulic analysis and design.

4.1.1 *Topographic and Bathymetric Data*

The channel geometry data in the model were obtained from the MicroStation and InRoads files supplied by the Project Engineer's Office (PEO), which were developed from topographic surveys performed by 1 Alliance in March 2020. The survey data were supplemented with 2019 Olympics South LiDAR data (Washington DNR LiDAR Portal 2020). Proposed channel geometry was developed from the proposed grading surface created by HDR. All survey and LiDAR information is referenced against the

North American Vertical Datum of 1988 (NAVD88) and WSDOT horizontal project datum. All elevations presented in this report are NAVD88.

4.1.2 *Model Extent and Computational Mesh*

The upstream and downstream hydraulic model extents are consistent with the survey data extents. LiDAR was used to supplement additional floodplain areas. The detailed survey data starts approximately 275 feet upstream of the existing culvert inlet and end 640 feet downstream of the existing culvert outlet, measured along the channel centerline. The computational mesh elements are a combination of patched (quadrilateral) and paved (triangular) elements, with finer resolution in the channel and larger elements in the floodplain. The existing mesh covers a total area of 328,836 SF, with 6,767 quadrilateral and 26,666 triangular elements (see Figure 45). The proposed mesh covers a total area of 327,542 SF. This is slightly different from existing because of holes in the mesh used to simulate a structure. The proposed mesh has 6,448 quadrilateral and 26,916 triangular elements (see Figure 46).

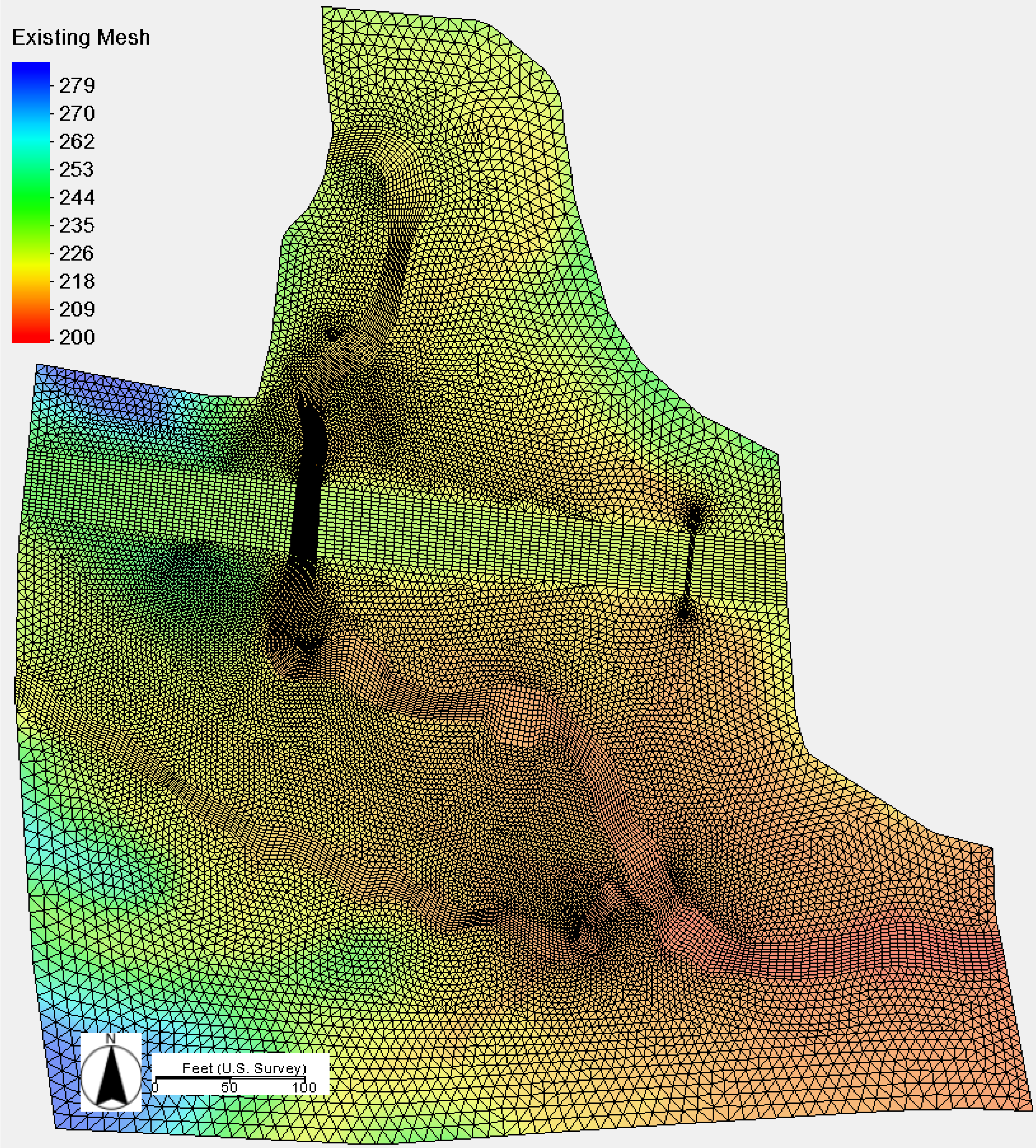

Figure 45: Existing-conditions computational mesh with underlying terrain

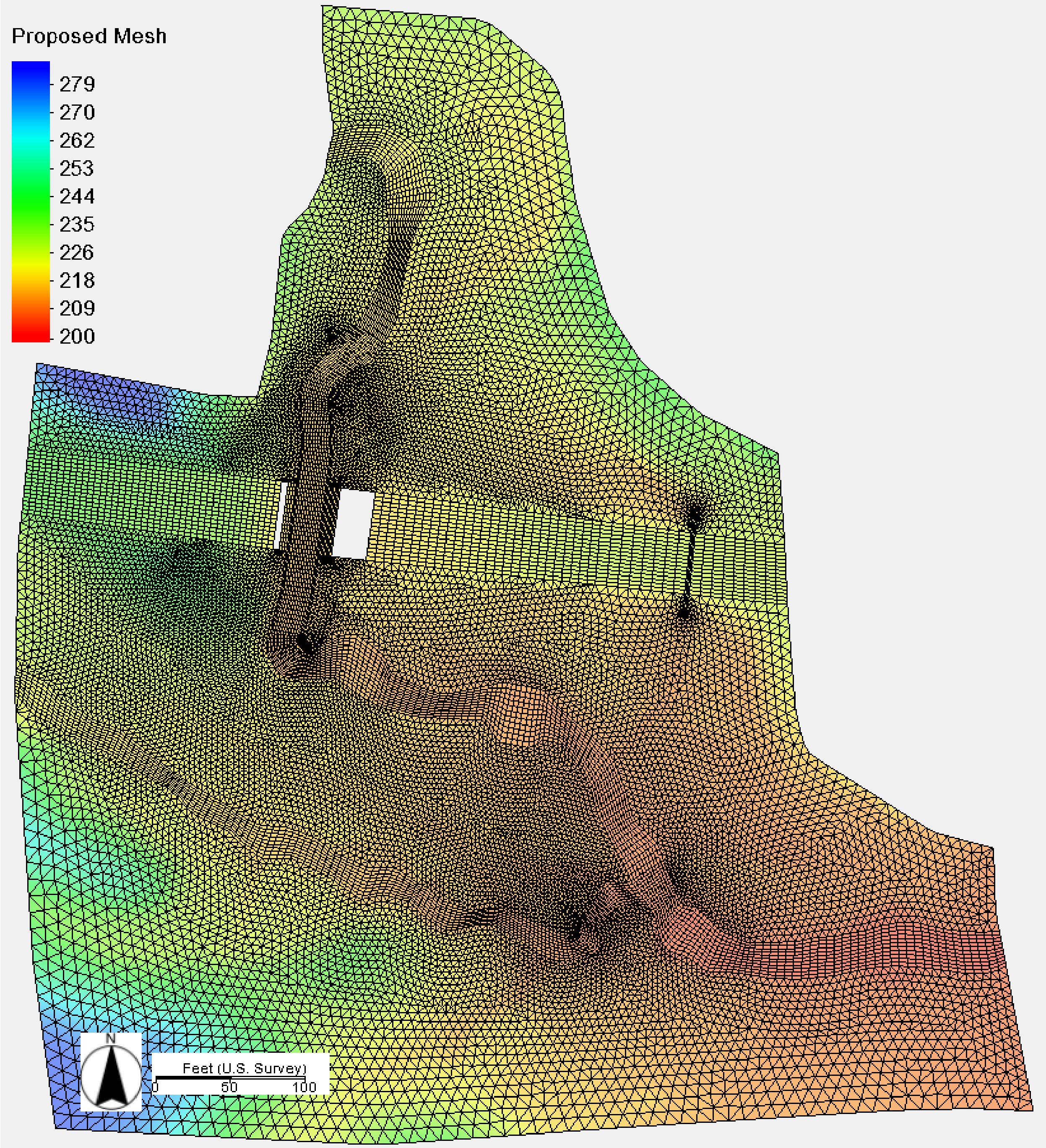

Figure 46: Proposed-conditions computational mesh with underlying terrain

4.1.3 *Materials/Roughness*

Manning's n values, estimated based on site observations, aerial photography, and standard engineering values (Chow 1959), are summarized below (Table 5). Roughness in the upstream and downstream floodplains is characterized by a roughness value of 0.12. The downstream and upstream channels are characterized by a roughness value of 0.045. See Figure 47 and Figure 48 for a spatial distribution of hydraulic roughness coefficient values.

Table 5: Manning's n hydraulic roughness coefficient values used in the SRH-2D model

Land Cover Type	Manning's n
Channel	0.045
Floodplains	0.12
Roadway	0.02
Grassy road embankment	0.03

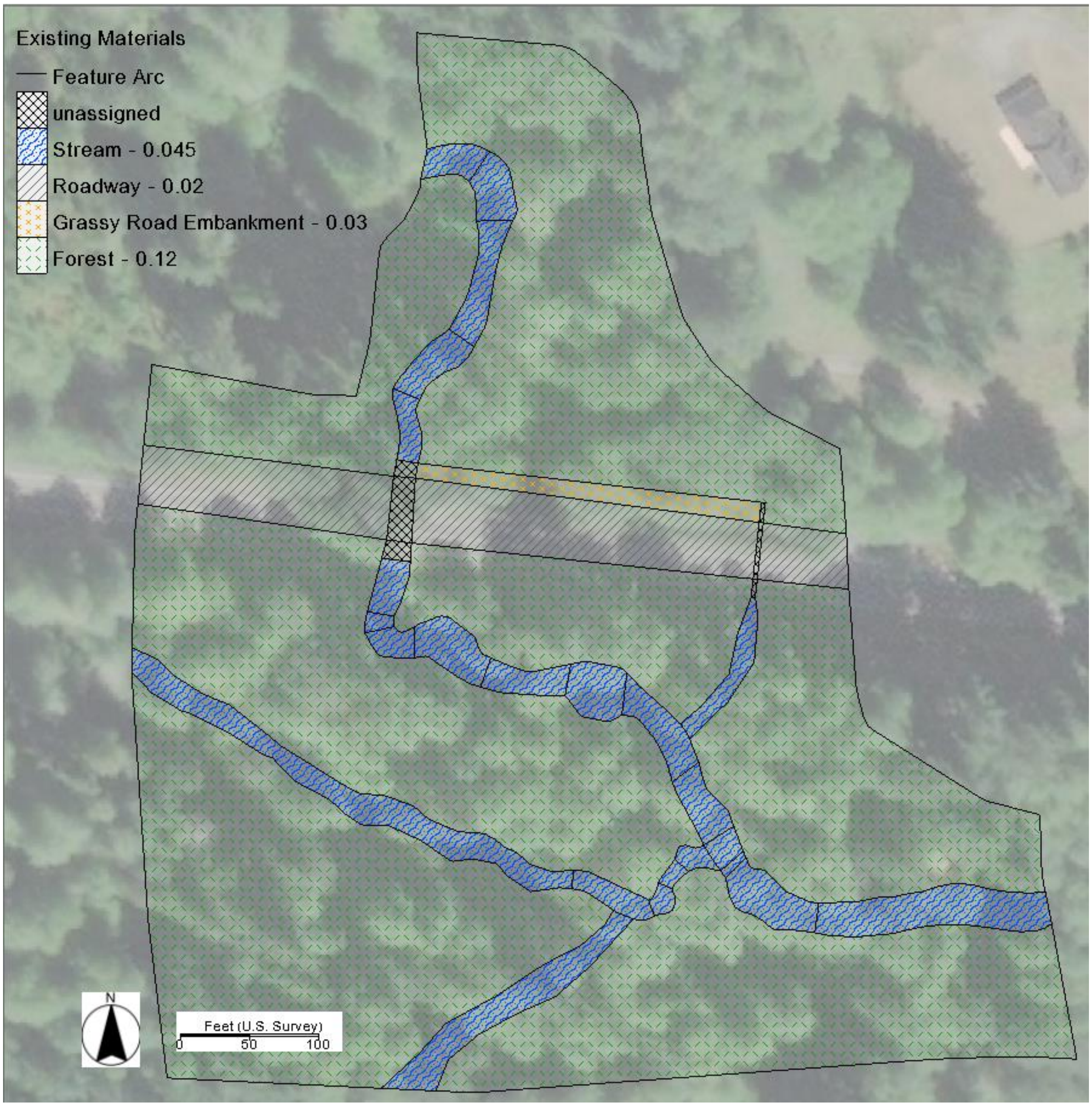

Figure 47: Spatial distribution of roughness values in existing-conditions SRH-2D model

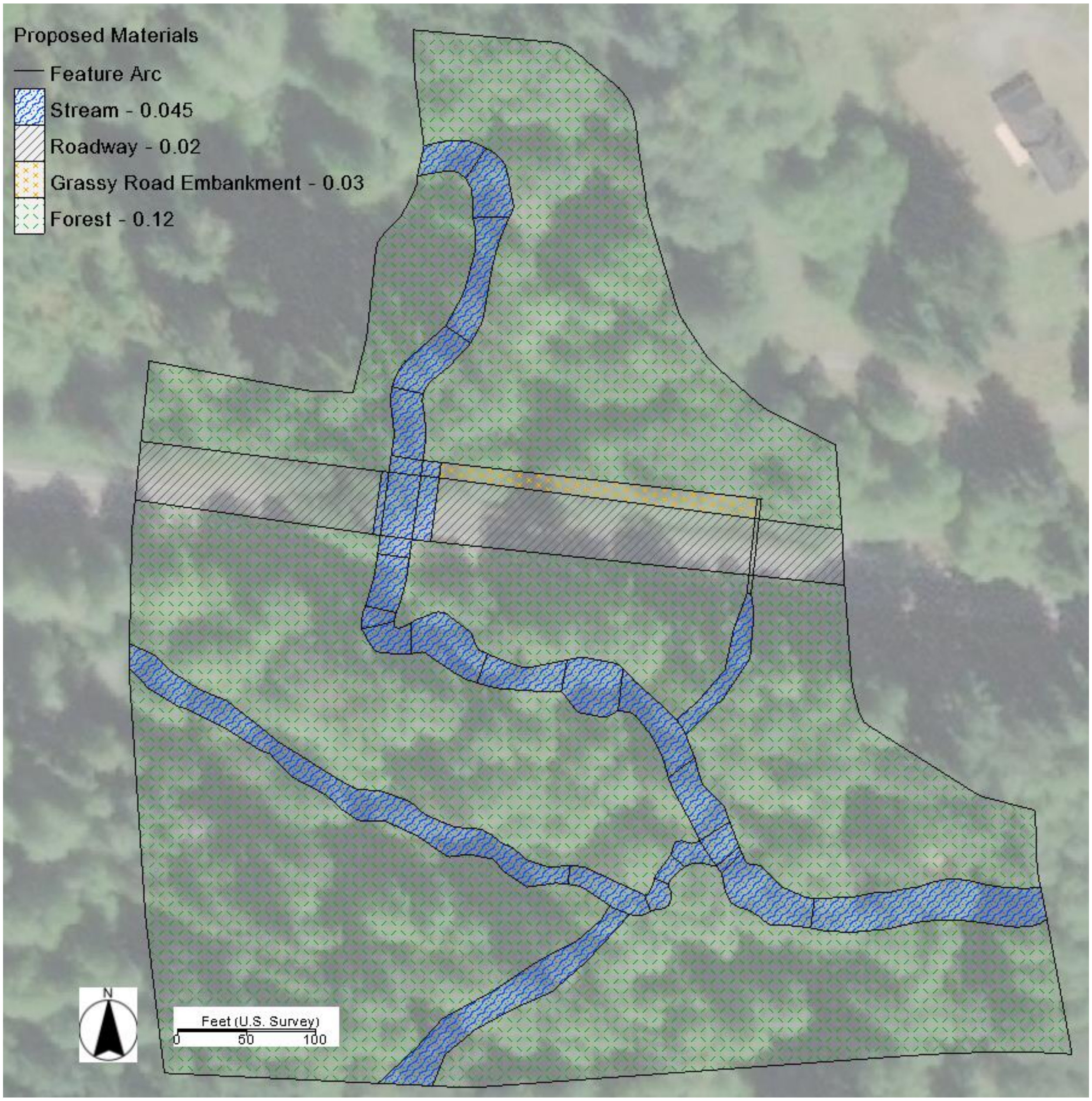

Figure 48: Spatial distribution of roughness values in proposed-conditions SRH-2D model

4.1.4 *Boundary Conditions*

Model simulations were performed using constant discharges ranging from the 2-year to 500-year peak flow events summarized in Section 3. External boundary conditions were applied at the upstream and downstream extents of the model domain and remained the same between the existing- and proposed-conditions runs. A constant flow rate was specified at the upstream external boundary condition, while a normal depth rating curve was specified at the downstream boundary. The downstream normal depth boundary condition rating curve was developed within SMS using the existing terrain, assuming a downstream slope of 1.7 percent as measured from the survey and a composite roughness of 0.045. See Figure 51 for the downstream boundary conditions. Model simulations were run for a sufficiently long duration until the results stabilized across the model domain.

An HY-8 internal boundary condition was specified in the existing-conditions model to represent the existing concrete box culvert crossing. The existing crossing was modeled as a 6-foot-diameter box culvert within HY-8. A Manning's roughness of 0.012 was assigned to the culvert, which was assumed to be unobstructed and free from any stream material within it. See Figure 49 for HY-8 inputs.

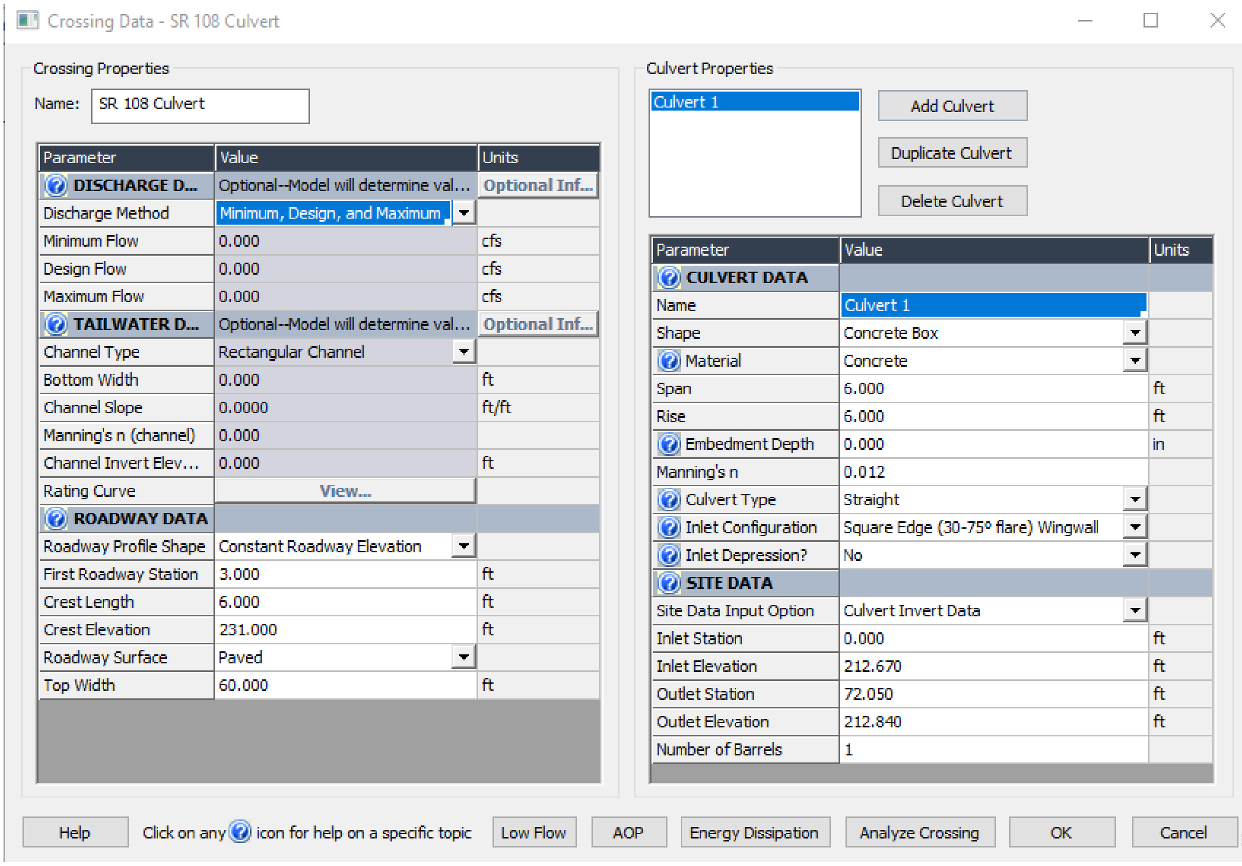

Figure 49: SR 108 HY-8 culvert parameters

A second HY-8 internal boundary condition was incorporated in both the existing- and proposed-conditions models to represent the circular concrete overflow culvert to the east of the main SR 108 crossing. This existing culvert was modeled as a 1.5-foot-diameter circular pipe within HY-8. A Manning's roughness of 0.012 was assigned to the culvert, which was assumed to be unobstructed and free from any stream material within the barrel. See Figure 50 for HY-8 inputs.

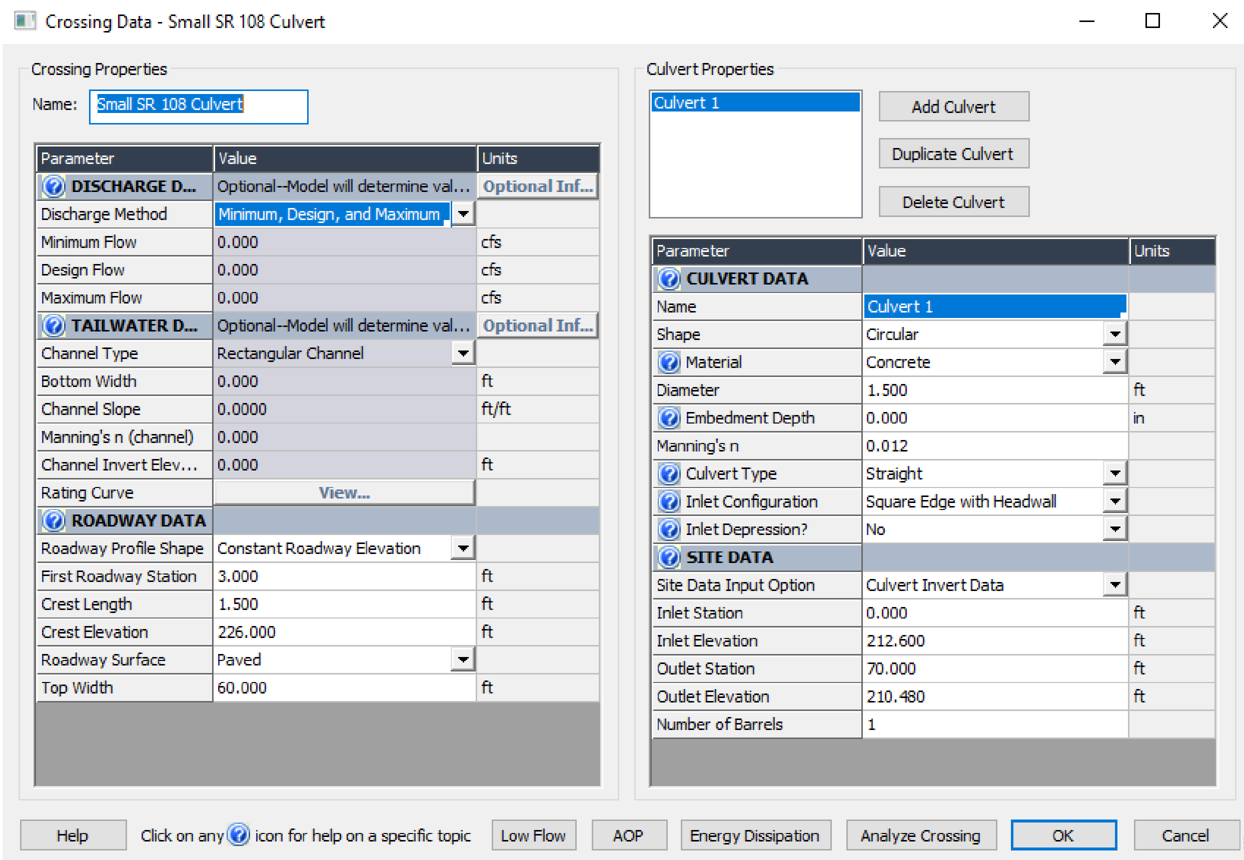

Figure 50: Overflow HY-8 culvert parameters

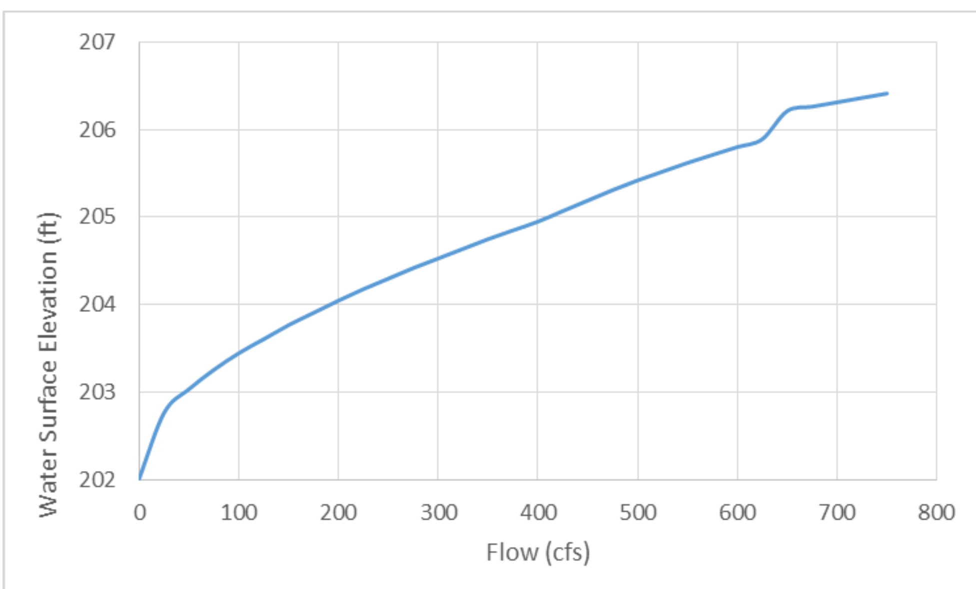

Figure 51: Downstream normal depth rating curve

4.1.5 *Model Run Controls*

Settings in the SRH-2D model control were kept consistent between existing- and proposed-conditions models. The model began at time zero and ended at 2 hours with a 0.5-second time step. The initial condition was dry and the default flow module was used.

4.1.6 *Model Assumptions and Limitations*

The SRH-2D hydraulic model was developed to determine the minimum hydraulic structure opening, establish the proposed structure low chord elevation (and associated freeboard), and characterize hydraulic parameters used to design the crossing. The use of a constant inflow rate is an appropriate assumption to meet the model objectives. Using a constant inflow rate provides a conservative estimate of inundation extents and water surface elevation (WSEL) associated with a given peak flow, which is used to determine the structure size and low chord.

Using the approach described in this study, each scenario is run for a sufficient time to fill storage areas and for water surface elevations to stabilize until flow upstream equals flow downstream. This modeling method does not account for the attenuation of peak flows between the actual upstream and downstream hydrographs, in particular with a large amount of storage upstream of the existing undersized culvert. During an actual runoff event, it is unlikely that the area upstream of the culvert would fill up entirely. An unsteady simulation could be used to route a hydrograph through the model to estimate peak flow attenuation for existing and proposed conditions. During an unsteady simulation, the areas upstream of the existing culvert would act as storage and, as a result, the flow downstream of the crossing would likely be less than the current design peak flow event. Estimates of the downstream increases to water surface elevation and flow based on the constant inflow model results may then underestimate the downstream flood impacts. An unsteady analysis is outside the current scope of this preliminary study, but could be considered at a later stage of design. Therefore, the changes to the peak flow rate downstream of the project cannot be quantified with this approach.

The model results and recommendations in this PHD Report are based on the conditions of the project site and the associated watershed at the time of this study. Any modifications to the site, man-made or natural, could alter the analysis, findings, and recommendations contained herein and could invalidate the analysis, findings, and recommendations. Site conditions, completion of upstream or downstream projects, upstream or downstream land use changes, climate changes, vegetation changes, maintenance practice changes, or other factors may change over time. Additional analysis or updates may be required in the future as a result of these potential changes.

4.2 Existing-Conditions Model Results

The existing-conditions model shows that the existing SR 108 crossing is undersized. All flows above the 2-year storm use the left floodplain to convey flow upstream of the culvert. At the 50-year flow and higher, the model shows that the existing crossing becomes inundated and flow is routed along the floodplain and roadside ditch to the east overflow culvert. Similar to upstream, downstream of the culvert all flows above the 2-year storm uses floodplains.

For the 100-year event, velocities within the upstream reference reach range from 6.5 to 7.5 feet per second (ft/s), and the velocities within the downstream reference reach range from 4.5 to 6.0 ft/s. High areas for velocity (10 to 15 ft/s for the 100-year event) include the culvert outlet and downstream of obstructions such as log jams or wood weirs.

Hydraulic characteristics are summarized within the main channel in Table 6. Locations of the cross sections are illustrated in Figure 52 and stream stationing in Figure 53.

The existing-conditions hydraulic profile is provided in Figure 54. The profile shows that water backwaters approximately 150 feet upstream of the existing culvert during the 100-year flood event. A cross section upstream of the culvert is provided in Figure 55. All other cross-section figures are provided in Appendix B.

Velocity magnitudes are illustrated at the 100-year event in Figure 56 and summarized for the main channel and floodplains in Table 7.

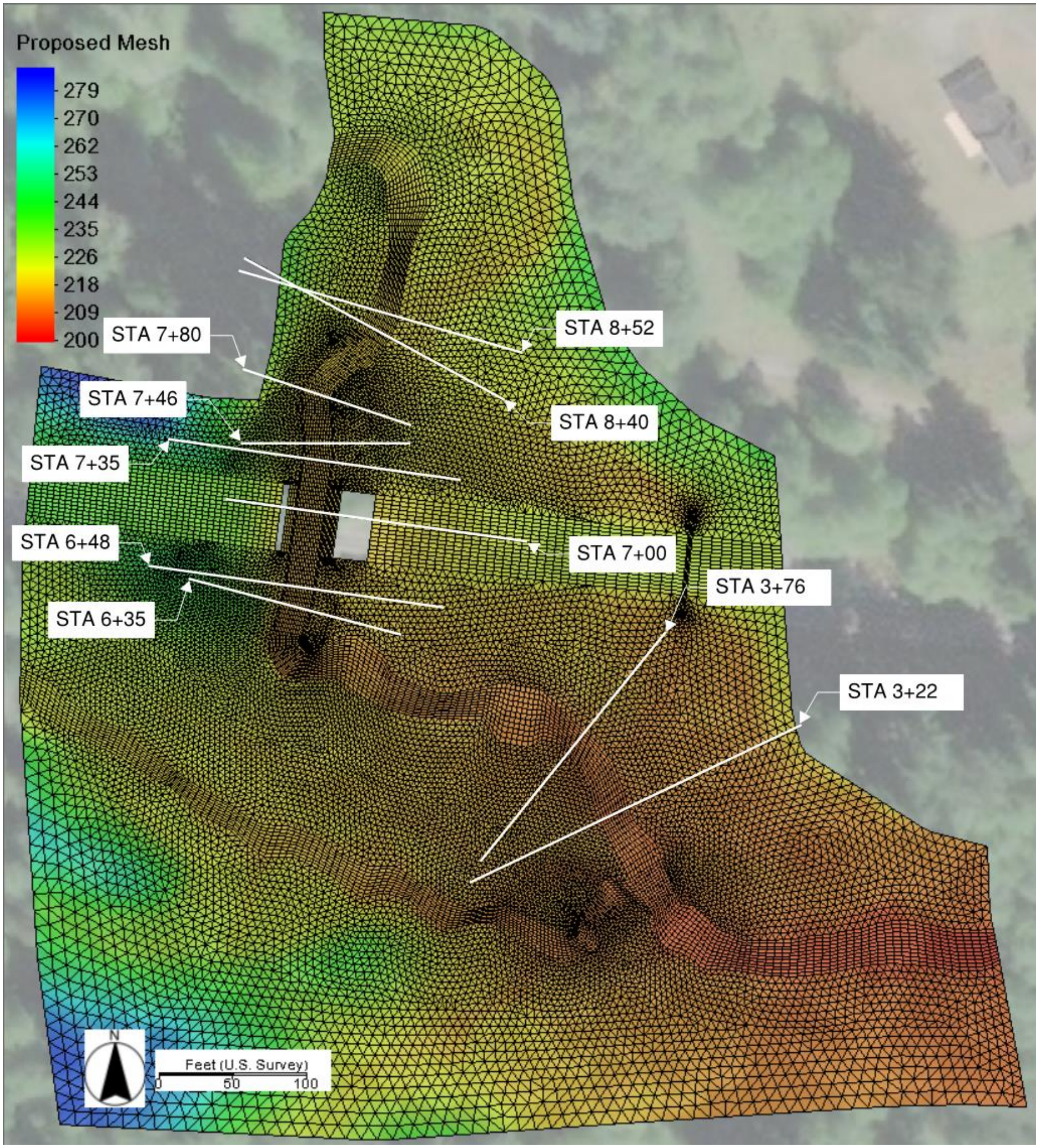

Figure 52: Locations of cross sections used for results reporting

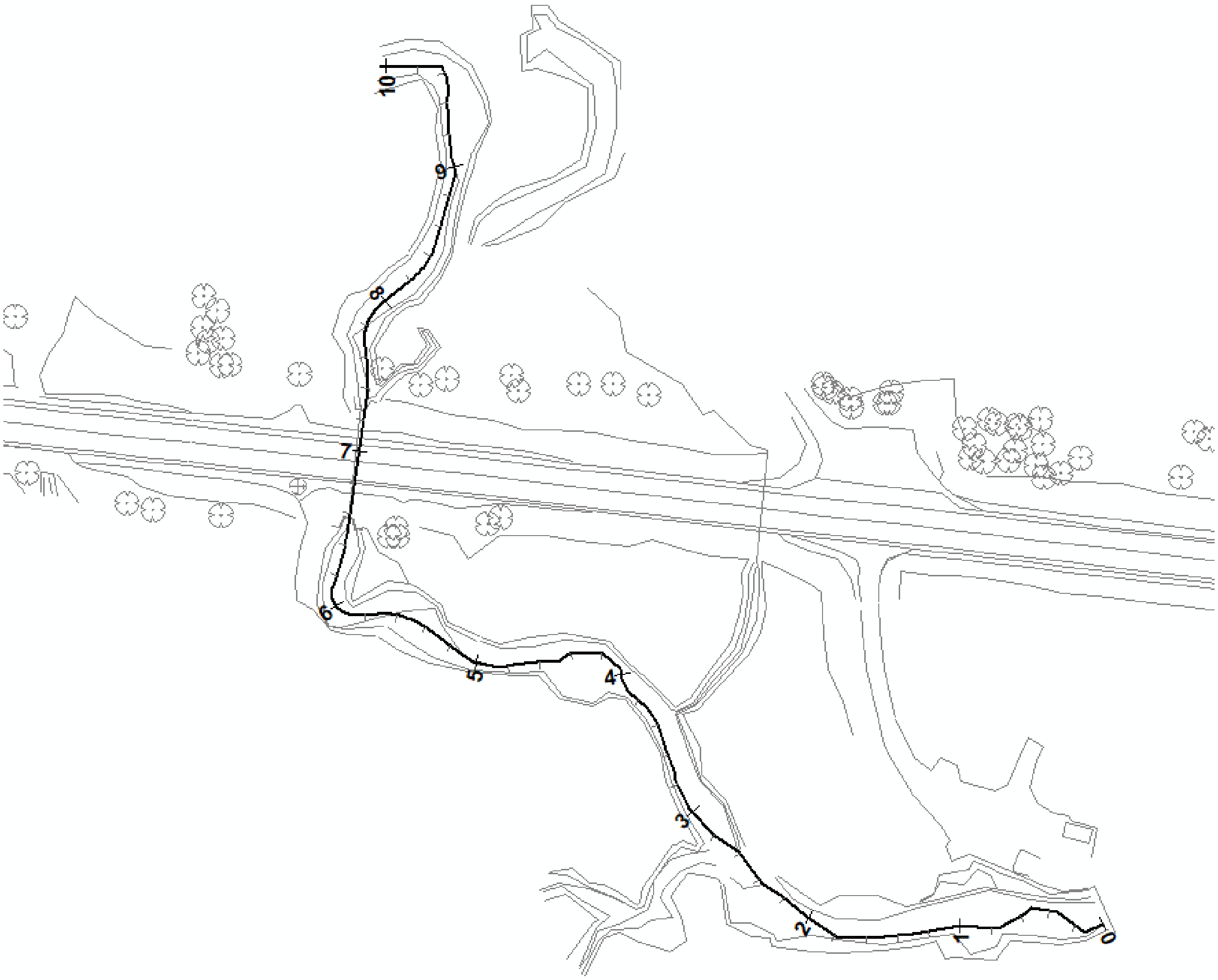

Figure 53: Longitudinal profile stationing for existing and proposed conditions

Table 6: Hydraulic results for existing conditions within the main channel

Hydraulic Parameter	Cross Section	2-year	25-year	50-year	100-year	500-year
Average water surface elevation (ft)	XS 3+22	209.6	210.8	211.0	211.2	211.6
	XS 3+76	210.3	211.1	211.3	211.5	211.9
	XS 6+35	215.0	215.5	215.6	215.6	215.7
	XS 6+48	215.0	215.3	215.3	215.3	215.4
	XS 7+35	216.8	219.6	220.0	220.9	223.0
	XS 7+46	216.8	219.6	220.1	220.9	223.1
	XS 7+80	216.7	219.7	220.1	221.0	223.1
	XS 8+40	218.6	219.6	220.1	220.9	223.1
	XS 8+52	218.8	219.6	220.0	220.9	223.1
Max depth (ft)	XS 3+22	2.1	3.3	3.5	3.7	4.1
	XS 3+76	1.6	2.5	2.7	2.9	3.2
	XS 6+35	1.4	1.9	2.0	2.0	2.1
	XS 6+48	1.5	2.0	2.1	2.2	2.4
	XS 7+35	3.8	6.6	7.0	7.9	10.0
	XS 7+46	2.6	5.4	5.9	6.8	8.9
	XS 7+80	1.6	4.7	5.1	6.0	8.2
	XS 8+40	1.2	2.3	2.7	3.5	5.7
	XS 8+52	1.3	2.1	2.5	3.3	5.5
Average velocity (ft/s)	XS 3+22	2.8	3.6	3.7	3.9	4.1
	XS 3+76	3.7	5.4	5.5	5.4	5.8
	XS 6+35	4.9	8.0	8.7	9.2	11.4
	XS 6+48	5.3	9.9	10.8	11.4	13.5
	XS 7+35	2.9	3.1	3.2	2.9	2.6
	XS 7+46	3.2	2.7	2.6	2.3	1.6
	XS 7+80	5.5	2.8	2.7	2.3	1.4
	XS 8+40	4.8	5.6	5.3	4.6	3.1
	XS 8+52	5.1	7.0	6.7	5.4	3.5
Average shear (lb/ft^2)	XS 3+22	0.4	0.7	0.7	0.8	0.9
	XS 3+76	0.8	1.3	1.4	1.3	1.4
	XS 6+35	1.5	3.7	4.3	4.9	7.4
	XS 6+48	1.9	5.9	6.8	7.5	10.4
	XS 7+35	0.4	0.3	0.3	0.3	0.2
	XS 7+46	0.5	0.3	0.2	0.2	0.1
	XS 7+80	2.0	0.3	0.3	0.2	0.1
	XS 8+40	1.3	1.5	1.3	0.8	0.3
	XS 8+52	1.6	2.4	2.0	1.2	0.4

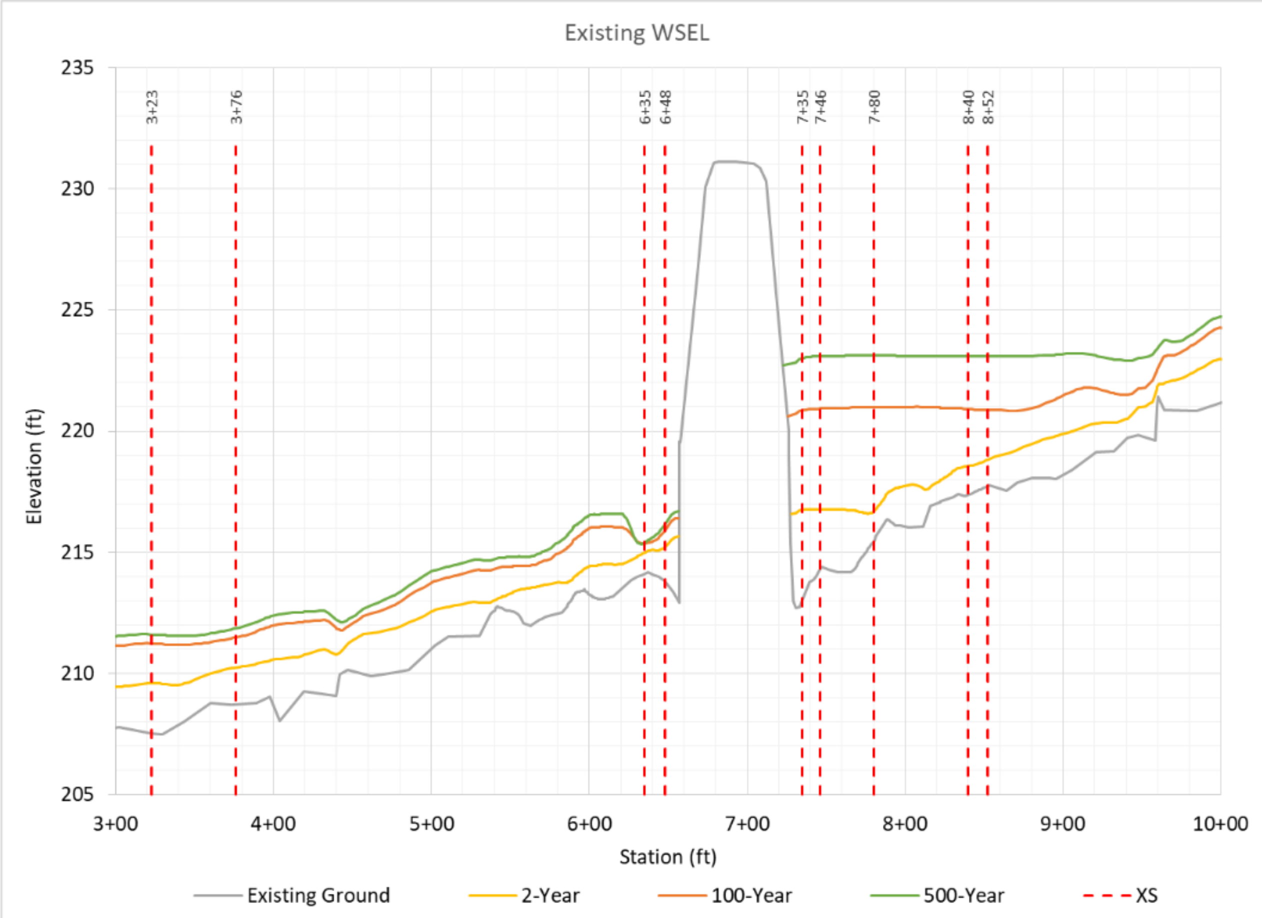

Figure 54: Existing-conditions water surface profiles

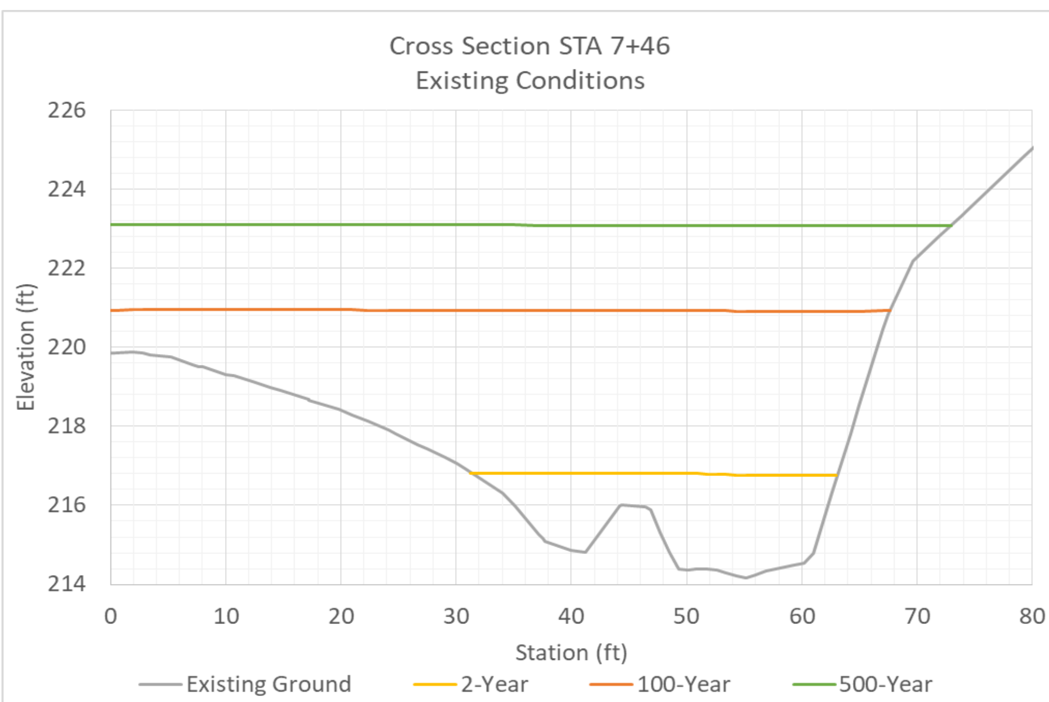

Figure 55: Typical upstream existing channel cross section

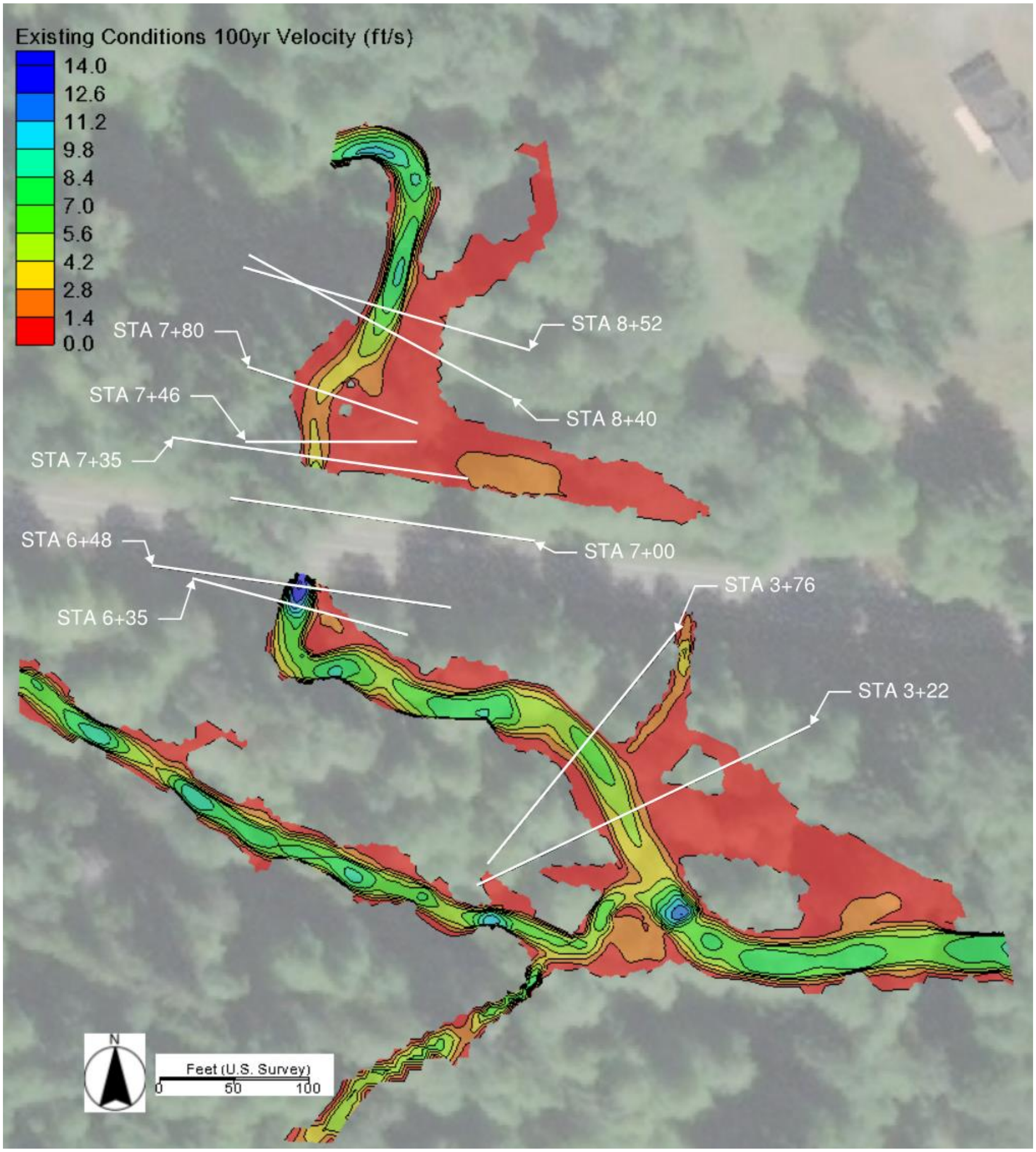

Figure 56: Existing-conditions 100-year velocity map with cross-section locations

Table 7: Existing-conditions velocities including floodplains at select cross sections

Location	Q100 Average Velocities (ft/s)		
	LOB[a]	Main Ch.	ROB[a]
Reference reach 4 (3+23)	0.6	3.9	0.2
Reference reach 3 (3+76)	1.6	5.4	1.2
Immediately downstream of structure (6+35)	1.4	9.2	1.8
Through structure downstream (6+48)	1.1	11.4	4.9
Through structure upstream (7+35)	0.4	2.9	1.3
Immediately upstream of structure (7+46)	0.6	2.3	1.6
Upstream of structure (7+80)	0.7	2.3	0.4
Reference reach 2 (8+40)	0.5	4.6	0.5
Reference reach 1 (8+52)	0.5	5.4	1.2

a. LOB/ROB locations determined from existing-conditions 2-year storm extent.

4.3 Natural Conditions

The UNT to Skookum Creek is a confined stream with a floodplain utilization ratio (FUR) of 2.8. Being so close to the threshold of an unconfined stream, a natural condition was simulated to help inform the proposed design. WSDOT's infrastructure (SR 108) was "removed" to create a proposed natural-conditions surface that mimics the existing conditions directly upstream and downstream of the crossing. This entails a wide left bank floodplain and grading the channel through the road embankment at a slope of 1.76 percent. For the 100-year storm within the restored natural area the entire width of the wetted channel is 38 feet across, with an average thalweg depth of 2.3 feet. The overflow culvert to the east is not activated for the flow events with the natural condition because of the removal of the backwater created by the existing culvert.

The velocity within the restored natural area is an average of 6.7 ft/s within the main channel for the 100-year event. At the upstream reference reach the velocity ranges from 7.7 to 8.4 ft/s. These velocities are higher than what was shown in existing because of backwater from the undersized culvert being removed. At the downstream reference reach the average main channel velocity ranges from 3.9 to 5.7 ft/s. High velocities within the natural conditions (10 to 12 ft/s for the 100-year event) are at the same areas as was seen in the existing conditions, downstream of obstructions. See Table 8 for detailed results within the main channel, included the 2080 projected Climate Change (CC) flows, and

Table 9 for detailed velocity results throughout the cross section.

Hydraulic characteristics are summarized within the main channel in Table 8. Locations of the cross sections are illustrated in Figure 59.

The natural-conditions hydraulic profile, provided in Figure 57, shows that water no longer backwaters upstream of the roadway during all flood events. A cross section located within the removed roadway is provided in Figure 58. All other cross-section figures are provided in Appendix B.

Velocity magnitudes are illustrated at the 100-year event in Figure 59 and summarized for the main channel and floodplains in Table 9.

Table 8: Hydraulic results for natural conditions within the main channel

Hydraulic Parameter	Cross Section	2-year	25-year	50-year	100-year	100-year CC	500-year
Average water surface elevation (ft)	XS 3+22	209.6	210.8	211.0	211.2	211.4	211.6
	XS 3+76	210.3	211.1	211.3	211.5	211.7	211.9
	XS 6+35	214.9	215.8	215.9	216.1	216.2	216.4
	XS 6+48	215.0	215.8	216.0	216.2	216.3	216.5
	XS 7+00 [a]	215.8	216.5	216.7	216.8	216.9	217.1
	XS 7+35	216.4	217.1	217.2	217.3	217.5	217.6
	XS 7+46	216.6	217.4	217.5	217.7	217.8	218.0
	XS 7+80	217.2	218.1	218.3	218.5	218.6	218.9
	XS 8+40	218.6	219.2	219.3	219.4	219.5	219.6
	XS 8+52	218.8	219.4	219.5	219.6	219.7	219.8
Max depth (ft)	XS 3+22	2.1	3.3	3.5	3.7	3.9	4.1
	XS 3+76	1.6	2.5	2.7	2.9	3.0	3.3
	XS 6+35	1.6	2.5	2.7	2.8	3.0	3.2
	XS 6+48	1.5	2.3	2.5	2.7	2.8	3.0
	XS 7+00 [a]	1.4	2.1	2.3	2.4	2.5	2.7
	XS 7+35	1.4	2.1	2.2	2.3	2.5	2.6
	XS 7+46	1.4	2.2	2.3	2.5	2.6	2.8
	XS 7+80	1.5	2.3	2.5	2.7	2.9	3.1
	XS 8+40	1.2	1.9	2.0	2.1	2.2	2.3
	XS 8+52	1.3	1.9	2.0	2.2	2.3	2.4
Average velocity (ft/s)	XS 3+22	2.8	3.6	3.7	3.9	4.0	4.1
	XS 3+76	3.7	5.4	5.6	5.7	5.9	6.1
	XS 6+35	3.9	5.1	5.3	5.6	5.8	6.1
	XS 6+48	4.3	5.7	5.9	6.1	6.3	6.5
	XS 7+00 [a]	4.5	6.2	6.5	6.7	6.9	7.2
	XS 7+35	4.6	6.5	6.9	7.2	7.5	7.8
	XS 7+46	4.6	6.3	6.6	6.8	6.9	7.1
	XS 7+80	4.5	5.8	5.8	5.9	5.9	5.9
	XS 8+40	4.8	6.9	7.3	7.7	8.1	8.6
	XS 8+52	5.1	7.6	8.0	8.4	8.8	9.2
Average shear (lb/ft^2)	XS 3+22	0.4	0.7	0.7	0.8	0.8	0.9
	XS 3+76	0.8	1.3	1.4	1.5	1.5	1.6
	XS 6+35	0.8	1.2	1.3	1.4	1.5	1.6
	XS 6+48	1.0	1.5	1.6	1.6	1.7	1.7
	XS 7+00 [a]	1.2	1.8	1.9	2.0	2.1	2.3
	XS 7+35	1.2	2.0	2.2	2.4	2.6	2.7
	XS 7+46	1.2	1.9	2.1	2.1	2.2	2.2
	XS 7+80	1.2	1.6	1.6	1.6	1.6	1.5
	XS 8+40	1.3	2.4	2.7	2.9	3.1	3.5
	XS 8+52	1.5	2.9	3.2	3.4	3.6	3.9

a. At removed road embankment, where new structure will be placed.

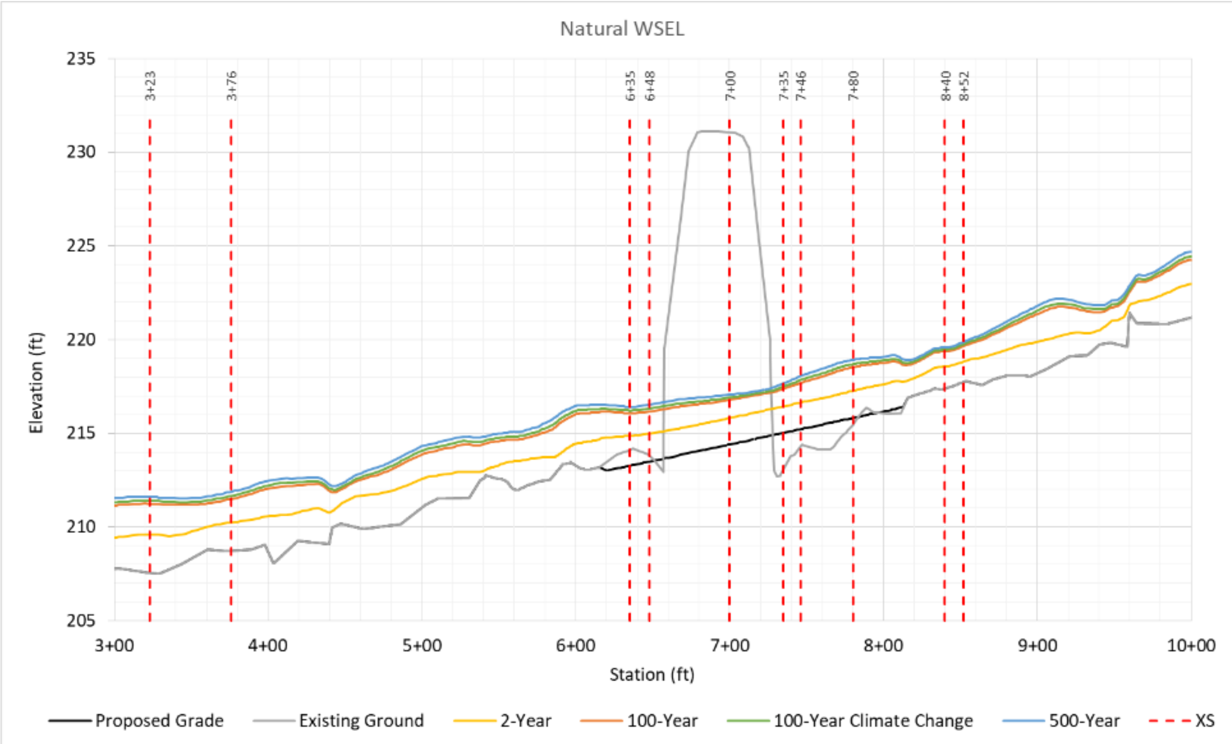

Figure 57: Natural-conditions water surface profiles

Figure 58: Natural conditions within removed structure

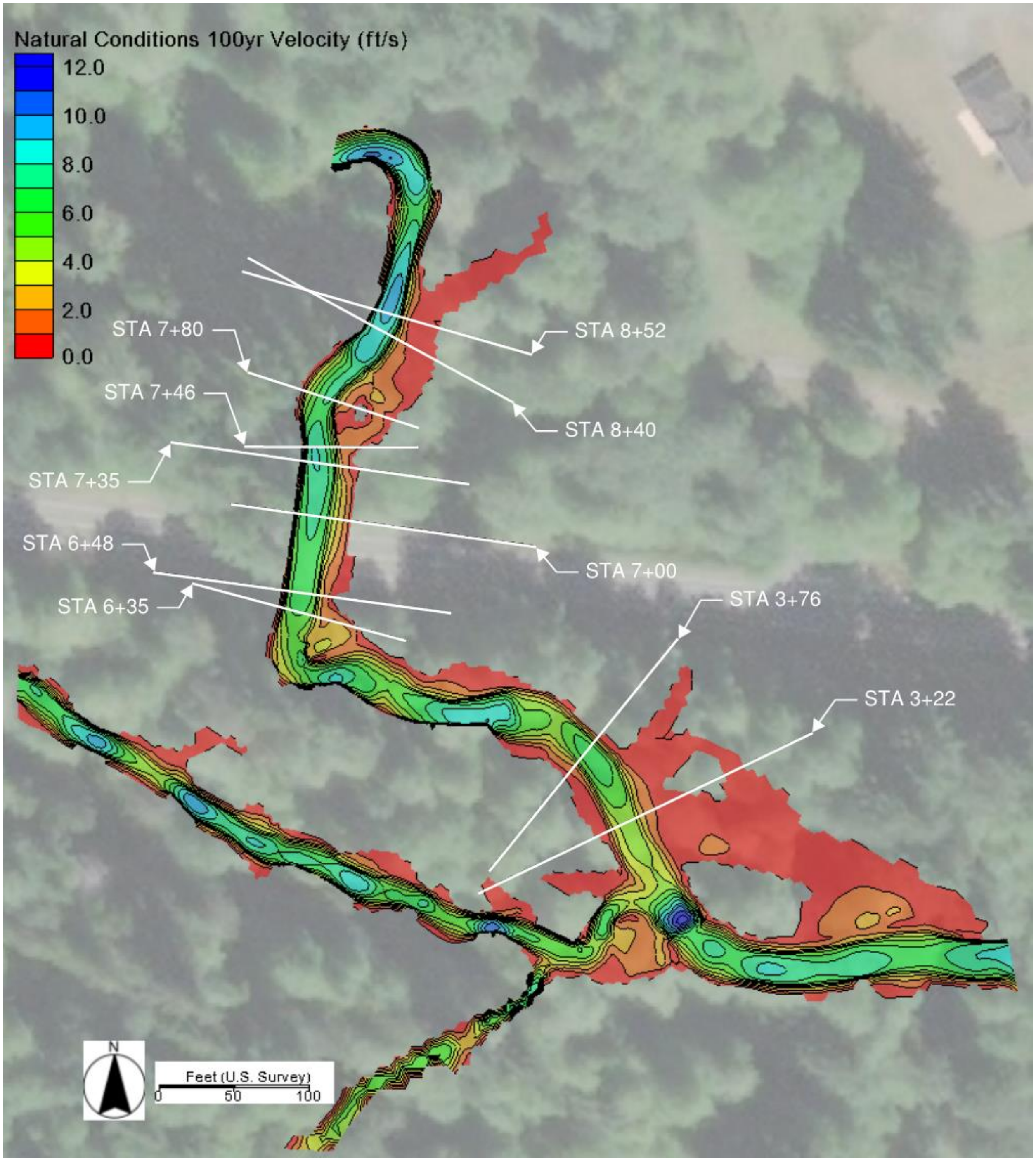

Figure 59: Natural-conditions 100-year velocity map with cross-section locations

Table 9: Natural-conditions velocities including floodplains at select cross sections

Location	Q100 Average Velocities (ft/s)		
	LOB[a]	Main Ch.	ROB[a]
Reference reach 4 (3+23)	0.6	3.9	0.2
Reference reach 3 (3+76)	1.9	5.7	1.4
Immediately downstream of structure (6+35)	1.9	5.6	1.6
Through structure downstream (6+48)	1.6	6.1	1.5
Through structure (7+00)	2.6	6.7	2.6
Through structure upstream (7+35)	1.4	7.2	2.2
Immediately upstream of structure (7+46)	1.4	6.8	2.5
Upstream of structure (7+80)	1.3	5.9	1.4
Reference reach 2 (8+40)	1.1	7.7	1.1
Reference reach 1 (8+52)	0.8	8.4	2.0

a. ROB/LOB locations determined from natural-conditions Q2 extent.

4.4 Channel Design

This section describes the channel design developed for the UNT to Skookum Creek at MP 5.54.

4.4.1 *Floodplain Utilization Ratio*

The FUR, also known as the entrenchment ratio, is the flood prone width divided by the bankfull width. Values less than 3 are considered confined and values greater than three are considered unconfined (WCDG 2013). The FUR is below 3.0; therefore, this is a confined channel. Using the 100-year flood, the upstream FUR is 2.8 and the downstream FUR is 2.9 within both reference reaches.

4.4.2 *Channel Planform and Shape*

The proposed channel planform and shape were determined from the reference reach and observations of the existing conditions via the site visit and survey data. Upstream and downstream of the SR 108 crossing the left bank is low and accessible to flood flows, while the right bank is against a steep hillside with no accessible floodplain. The proposed cross section is designed to mimic the existing channel and a lower left floodplain incorporated in the proposed grading, as well as within the structure (see Figure 60).

The proposed channel is expected to perform similarly to the existing channel reference reach. Based on the proposed hydraulic model the 2-year flow is at the grade break of the left floodplain, similar to the reference reach.

A low-flow channel will be added in later stages of the project that connects habitat features together so that the project is not a low-flow barrier. The low-flow channel will be as directed by the engineer in the field.

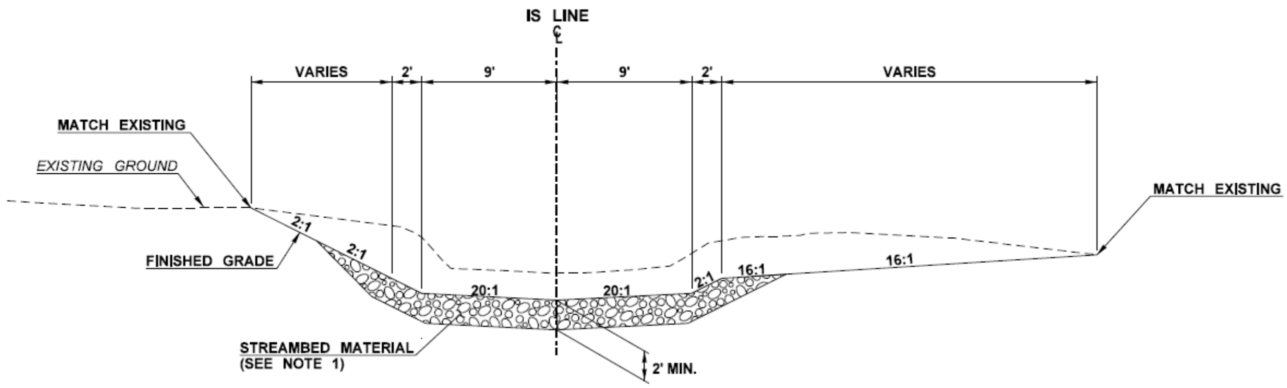

Figure 60: Design cross section

4.4.3 *Channel Alignment*

The channel grading totals 193 LF, with grading 87 LF upstream and 37 LF downstream of the existing structure. The channel generally follows the same horizontal planform shape and alignment as the existing conditions.

4.4.4 *Channel Gradient*

The WCDG recommends that the proposed culvert bed gradient not be more than 25 percent steeper than the existing stream gradient upstream of the crossing (WCDG Equation 3.1). The proposed channel gradient is 1.76 percent and the average upstream channel gradient is approximately 2.1 percent, resulting in a slope ratio of 0.84. Downstream of the crossing the average gradient is approximately 1.5 percent.

By keeping the proposed graded stream at a slope similar to the existing stream, and with no observed significant signs of existing aggradation or degradation, aggradation or long-term degradation is not anticipated.

4.5 Design Methodology

The proposed fish passage design was developed using the 2013 *Water Crossing Design Guidelines* and WSDOT *Hydraulics Manual* (WSDOT 2019). Using the guidance in these two documents, the confined bridge design method was determined to be the most appropriate at this crossing because of the bankfull width and FUR.

The bankfull width was measured to be 23.5 feet, which is greater than the 15.0-foot threshold to consider stream simulation; therefore, the bridge method was used. The floodplain width of the 100-year storm was not 3 times greater than the bankfull width so that did not require a move to an unconfined bridge.

4.6 Future Conditions: Proposed 35-Foot Minimum Hydraulic Opening

The hydraulic opening is defined as the width perpendicular to the creek beneath the proposed structure that is necessary to convey the design flow and allow for natural geomorphic processes. The hydraulic opening assumes vertical walls at the edge of the minimum hydraulic opening width unless otherwise specified.

The starting point for the design of all WSDOT structures is Equation 3.2 of the WCDG, rounded up to the nearest whole foot. For this crossing, a minimum hydraulic opening of 31.0 feet was determined to be the minimum starting point, based on the 23.5-foot design bankfull width. The confined bridge methodology also includes an additional Factor of Safety recommendation. There were signs of bank erosion at locations of LWM within the channel. Therefore, a 50 percent Factor of Safety was used and applied to the bankfull width to account for any lateral migration that may occur in the proposed channel based on observations from the natural conditions model. This resulted in a minimum hydraulic opening of 35.0 feet (35.0 feet divided by 23.5 feet). This structure size would span any of the observed bank erosion and widened bankfull widths.

The proposed design surface was created based on existing conditions directly upstream and downstream of the crossing and taking into consideration the natural-conditions simulation. This resulted in a proposed surface with a wider left bank and an overall slope of 1.76 percent. The proposed structure is not centered on the stream thalweg because the floodplain is present only on the left bank. The left abutment is placed 19 feet to the left of the thalweg and the right abutment is placed 16 feet from the thalweg. This configuration creates an 8-foot-wide left bank floodplain within the structure. This was simulated in the SRH-2D model by creating voids in the mesh that were offset from the thalweg. In the model, the 2-year flood event remains within the banks with some very minor floodplain activation on the left bank, typical for the existing conditions within the reference reaches. For the 100-year event within the structure the wetted channel spans 31.5 feet across reaching the left side of the structure, with an average thalweg depth of 2.4 feet. The overflow culvert to the east is not activated for any of the flow events with the proposed condition.

Comparing the proposed results and natural results within the structure, the 2-year, 100-year water surface elevation and 100-year climate change (CC) water surface elevation stay the same. The 500-year water surface elevation increases approximately 0.1 foot within the structure from the natural to proposed conditions.

The velocity within the structure is an average of 7.5 ft/s at the center of the channel for the 100-year event. At the upstream reference reach the velocity ranges from 8.7 to 9.4 ft/s. These velocities are higher than what was shown in existing, most likely due to backwater from the undersized culvert. Immediately downstream of the culvert outlet, velocities decreased significantly from 9.2 to 11.4 ft/s at the existing conditions to 5.6 to 6.1 ft/s for the proposed conditions. At the downstream reference reach the velocity ranges from 5.5 to 6.4 ft/s. High velocities within the proposed conditions (10 to 12 ft/s for the 100-year event) are at the same areas as was seen in the existing conditions, downstream of obstructions.

Hydraulic characteristics are summarized within the main channel in Table 10. Locations of the cross sections are illustrated in Figure 64.

The proposed-conditions hydraulic profile is provided in Figure 61. The profile shows that water no longer backwaters upstream of the roadway during all flood events. A cross section located upstream of the structure and within the structure is provided in Figure 62 and Figure 63, respectively. All other cross-section figures are provided in Appendix B.

Velocity magnitudes are illustrated at the 100-year event in Figure 64 and summarized for the main channel and floodplains in Table 11.

Table 10: Hydraulic results for proposed conditions within the main channel

Hydraulic Parameter	Cross Section	2-year	25-year	50-year	100-year	100-year CC	500-year
Average water surface elevation (ft)	XS 3+22	209.6	210.8	211.0	211.2	211.4	211.6
	XS 3+76	210.3	211.1	211.3	211.5	211.7	211.9
	XS 6+35	214.9	215.8	215.9	216.1	216.2	216.4
	XS 6+48	215.0	215.8	216.0	216.2	216.3	216.5
	XS 7+00 [a]	215.8	216.5	216.7	216.8	216.9	217.1
	XS 7+35	216.4	217.1	217.2	217.4	217.5	217.7
	XS 7+46	216.6	217.4	217.5	217.7	217.8	218.0
	XS 7+80	217.2	218.1	218.3	218.5	218.6	218.9
	XS 8+40	218.6	219.2	219.3	219.4	219.5	219.6
	XS 8+52	218.8	219.4	219.5	219.6	219.7	219.8
Max depth (ft)	XS 3+22	2.1	3.3	3.5	3.7	3.9	4.1
	XS 3+76	1.6	2.5	2.7	2.9	3.0	3.3
	XS 6+35	1.6	2.5	2.7	2.8	3.0	3.2
	XS 6+48	1.5	2.3	2.5	2.7	2.8	3.0
	XS 7+00 [a]	1.4	2.1	2.3	2.4	2.5	2.7
	XS 7+35	1.4	2.1	2.2	2.4	2.5	2.7
	XS 7+46	1.4	2.2	2.3	2.5	2.6	2.8
	XS 7+80	1.5	2.3	2.5	2.7	2.9	3.1
	XS 8+40	1.2	1.9	2.0	2.1	2.2	2.3
	XS 8+52	1.3	1.9	2.0	2.2	2.3	2.4
Average velocity (ft/s)	XS 3+22	2.8	3.6	3.7	3.9	4.0	4.1
	XS 3+76	3.7	5.4	5.6	5.7	5.9	6.1
	XS 6+35	3.9	5.1	5.3	5.6	5.8	6.1
	XS 6+48	4.3	5.7	5.9	6.1	6.3	6.5
	XS 7+00 [a]	4.5	6.2	6.5	6.8	7.0	7.3
	XS 7+35	4.6	6.5	6.9	7.2	7.4	7.7
	XS 7+46	4.6	6.3	6.6	6.8	6.9	7.1
	XS 7+80	4.5	5.8	5.9	5.9	5.9	5.9
	XS 8+40	4.8	6.9	7.3	7.7	8.1	8.6
	XS 8+52	5.1	7.6	8.0	8.4	8.8	9.2
Average shear (lb/ft^2)	XS 3+22	0.4	0.7	0.7	0.8	0.8	0.9
	XS 3+76	0.8	1.3	1.4	1.5	1.5	1.6
	XS 6+35	0.8	1.2	1.3	1.4	1.5	1.5
	XS 6+48	1.0	1.5	1.6	1.6	1.7	1.8
	XS 7+00 [a]	1.2	1.8	1.9	2.1	2.2	2.3
	XS 7+35	1.2	2.1	2.2	2.4	2.5	2.6
	XS 7+46	1.2	2.0	2.1	2.1	2.2	2.2
	XS 7+80	1.2	1.6	1.6	1.6	1.6	1.5
	XS 8+40	1.3	2.4	2.7	2.9	3.1	3.5
	XS 8+52	1.5	2.9	3.2	3.4	3.6	3.9

a. Within structure.

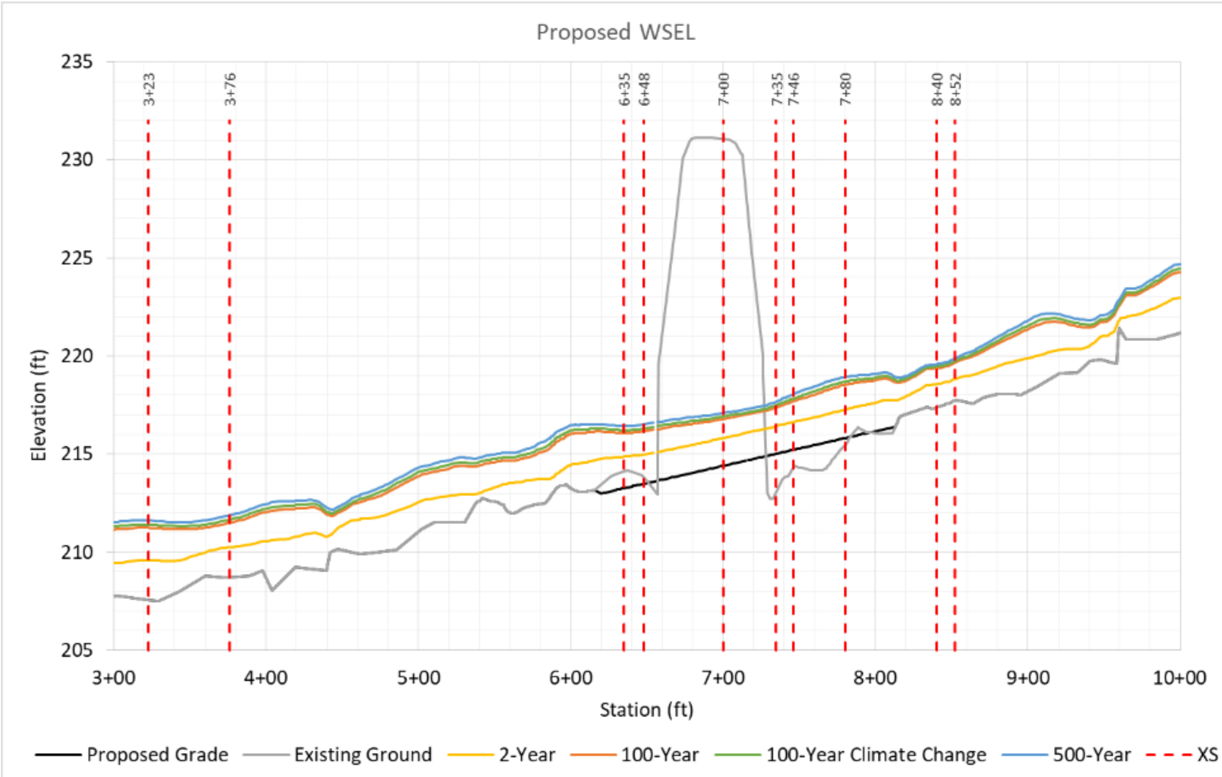

Figure 61: Proposed-conditions water surface profiles

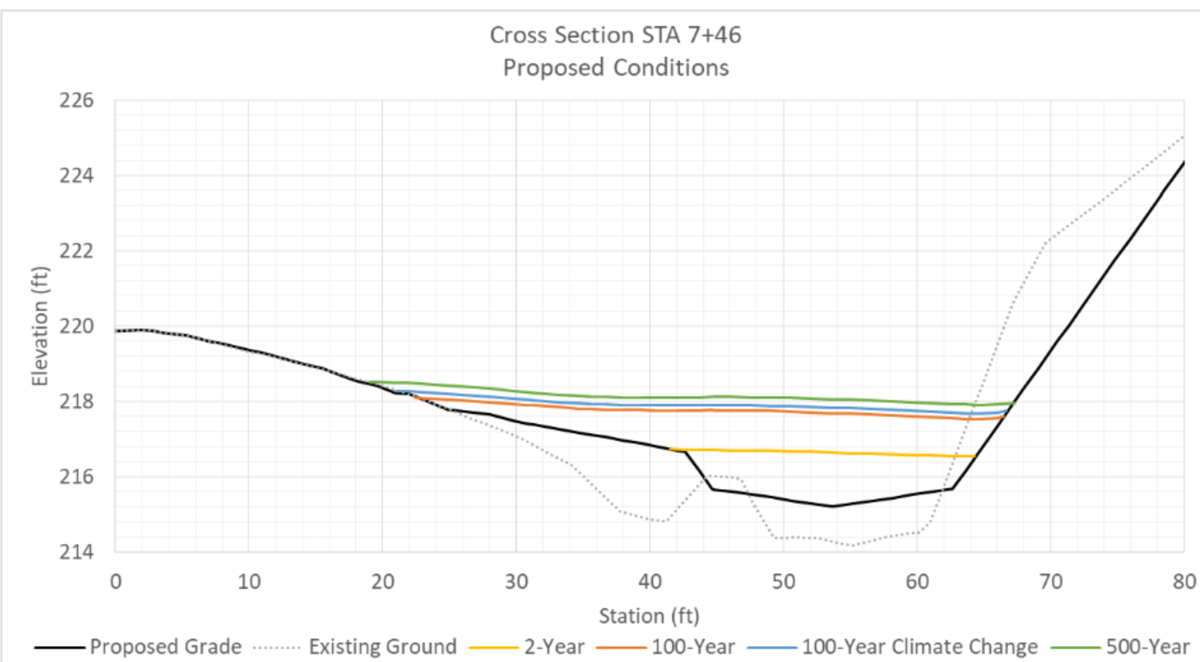

Figure 62: Typical upstream proposed channel cross section

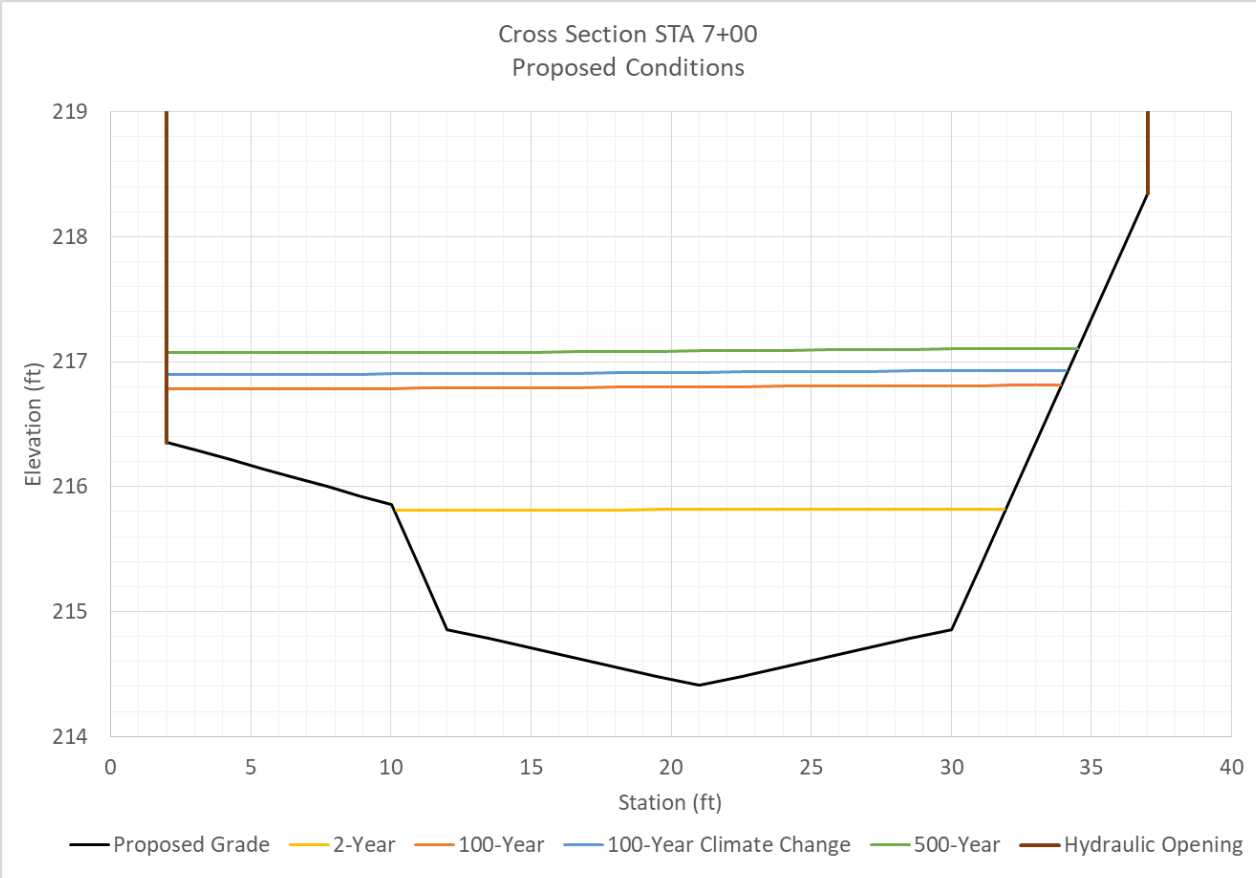

Figure 63: Typical channel cross section through proposed structure

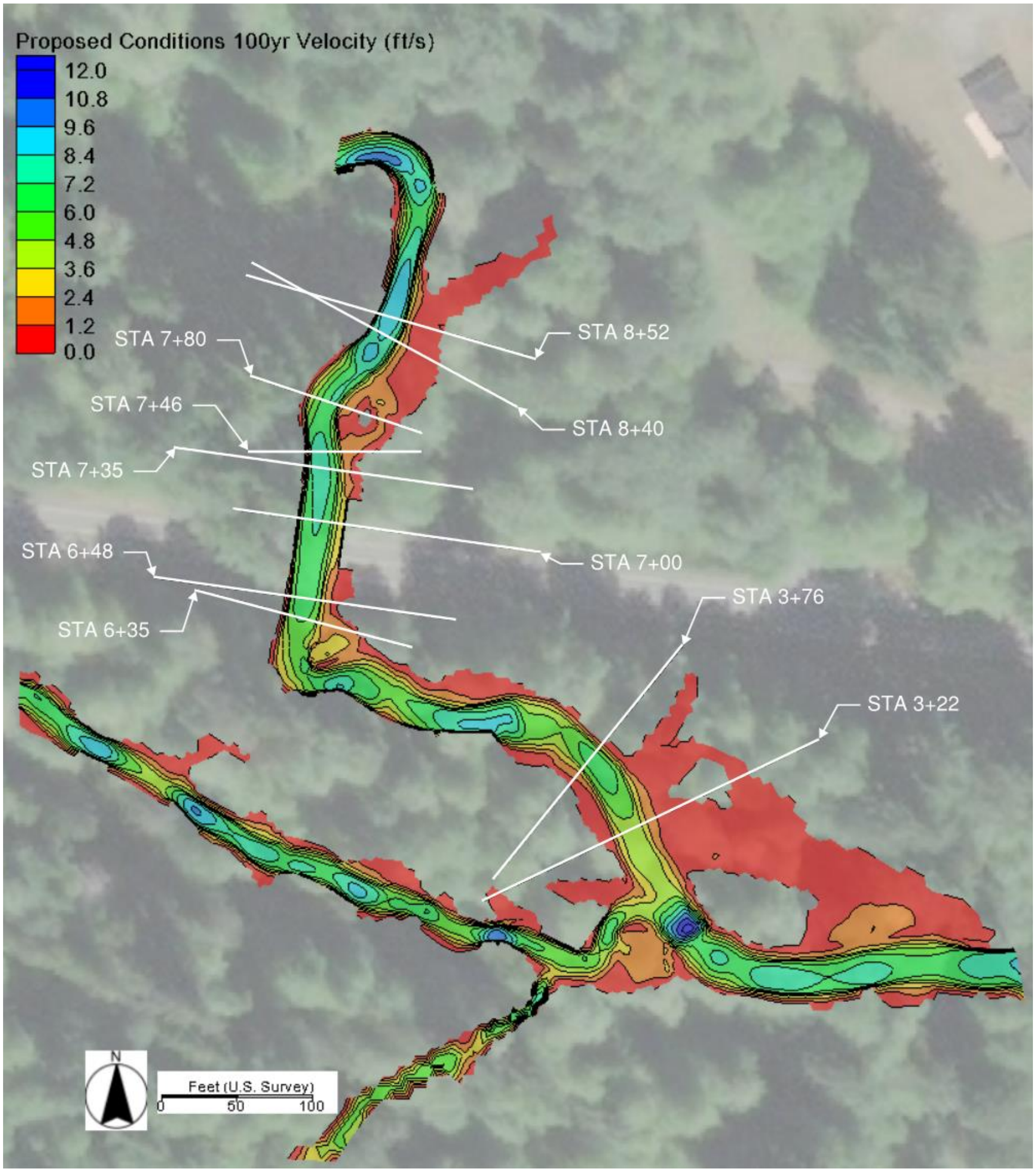

Figure 64: Proposed-conditions 100-year velocity map

Table 11: Proposed velocities including floodplains at select cross sections

Location	Q100 Average Velocities (ft/s)		
	LOB[a]	Main Ch.	ROB[a]
Reference reach 4 (3+23)	0.6	3.9	0.2
Reference reach 3 (3+76)	1.9	5.7	1.4
Immediately downstream of structure (6+35)	1.9	5.6	1.6
Through structure downstream (6+48)	1.4	6.1	1.5
Through structure (7+00)	3.4	6.8	3.1
Through structure upstream (7+35)	1.5	7.2	2.2
Immediately upstream of structure (7+46)	1.2	6.8	2.7
Upstream of structure (7+80)	1.3	5.9	1.4
Reference reach 2 (8+40)	1.1	7.7	1.1
Reference reach 1 (8+52)	0.8	8.4	2.0

a. ROB/LOB locations determined from existing-conditions Q2 extent.

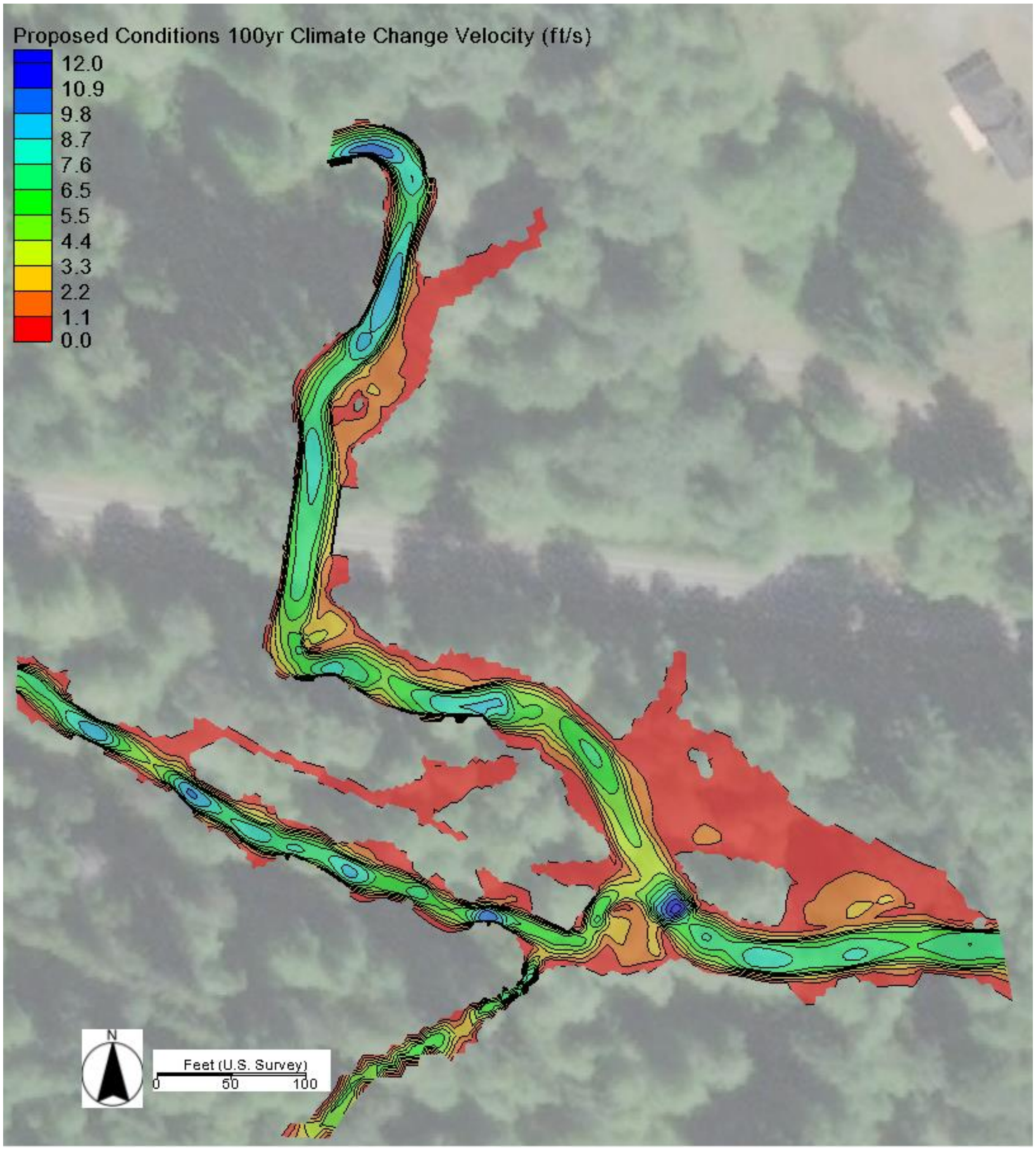

Figure 65: Proposed-conditions 2080 predicted 100-year velocity map

4.7 Water Crossing Design

This section describes the water crossing design developed for the UNT to Skookum Creek at MP 5.54.

4.7.1 *Structure Type*

No structure type has been recommended by Headquarters Hydraulics. The layout and structure type will be determined at later project phases.

4.7.2 *Minimum Hydraulic Opening Width and Length*

Using Equation 3.2 of the WCDG, a minimum 31.0-foot opening was considered for the confined bridge based on the 23.5-foot bankfull width. Because this crossing is being designed using the confined bridge methodology a 50 percent Factor of Safety was used and applied to the bankfull width to account for any lateral migration that may occur in the proposed channel. During the site visit, localized bank erosion was observed and the additional Factor of Safety creates a structure size that spans the channel and locations of active erosion; see Section 2.8.5 for observations of lateral migration.

Based on the factors described above, a minimum hydraulic opening of 35 feet was determined to be necessary to allow for natural processes to occur under current flow conditions. The projected 2080 100-year flow event was evaluated and the velocity comparisons for these flow rates can be seen in Table 12 below.

Table 12: Velocity comparison for 35-foot structure

Location	100-Year Velocity (ft/s)	Projected 100-Year Velocity (ft/s)	Difference (ft/s)
Reference reach (8+40)	7.7	8.1	0.4
Upstream of structure	6.8	6.9	0.1
Through structure	6.8	7.0	0.2
Downstream of structure	5.6	5.8	0.2
Velocity ratio	1.0	1.0	-

Note: Velocity ratio calculated as Vstructure/Vupstream.

No size increase was determined to be necessary to accommodate climate change.

A minimum hydraulic opening of 35 feet is recommended up to a maximum structure length of 75 feet (approximate length of the existing culvert). If the structure length needs to be increased beyond this, the hydraulics should be re-verified.

4.7.3 *Freeboard*

The WCDG recommends the prevention of excessive backwater rise and increased main channel velocities during floods that might lead to scour of the streambed and coarsening of the stream substrate, allow the free passage of debris expected to be encountered, and generally suggests a minimum 3-foot freeboard for streams of this size above the 100-year water surface elevation. WSDOT is incorporating climate resilience in freeboard, where practicable, and has evaluated freeboard at both the 100-year water surface elevation and the projected 2080 100-year water surface elevation.

The minimum required freeboard at this location based on bankfull width was 3 feet at the 100-year flow event. The water depth at the 100-year flow event at the deepest point within the structure is 2.7 feet. The 2080 projected 100-year water depth at this point is 2.8 feet. A minimum structure height of 5.8 feet above the thalweg is required to meet the minimum freeboard requirement.

Long-term degradation, aggregation, and debris risk were also evaluated at this location. Minimal long-term degradation and aggregation are expected within the channel based on existing conditions and gradient; therefore, no additional height was provided to the structure.

4.7.3.1 *Past Maintenance Records*

As discussed previously in Section 2.4, WSDOT Area 16 Maintenance was contacted to determine whether there were ongoing maintenance problems at the existing structure due to LWM racking at the inlet or sedimentation. The maintenance records were requested but not yet provided.

4.7.3.2 *Wood and Sediment Supply*

The Tributary is large enough to transport LWM at high flows and has the potential to recruit LWM locally from its banks because of the heavily forested area it flows through. During the site visit there were signs of wood mobilized previously based on the presence of downstream log jams. LWM transport may be somewhat limited by the upstream barrier at the BNSF railroad. Logging is present in the area near the UNT to Skookum Creek but typically occurs farther downstream based on historical aerial photos. Agriculture is also present within the area.

This reach has a high potential of recruiting more woody material because of stream size and the existing forested area directly adjacent to the channel; existing LWM is described further in Section 2.8.6. Aggradation is not anticipated and is discussed further in Section 4.4.4.

4.7.3.3 *Flooding*

The existing and proposed roadway is not at risk of inundation because of the height of the roadway prism. As stated in Section 2.3, the crossing is not within a regulated floodplain. Currently the existing crossing creates a backwatered condition upstream during higher flows and uses an overflow culvert to the east of the crossing. The proposed condition will significantly reduce this backwatering and all flows go through the main channel and decreasing velocities within and downstream of the culvert.

4.7.3.4 *Future Corridor Plans*

There are currently no long-term plans to improve SR 108 through this corridor.

5 Streambed Design

This section describes the streambed design developed for the UNT to Skookum Creek at MP 5.54.

5.1 Bed Material

The proposed bed material gradation was created using standard WSDOT specification material to mimic the gradation documented in the pebble count as closely as possible; the proposed D_{50} is within 0.1 inch of the observed D_{50}. The proposed mix will consists of 60 percent streambed sediment and 40 percent 6-inch streambed cobbles. A comparison of the observed and proposed streambed material size distribution is provided in Table 13.

Table 13: Comparison of observed and proposed streambed material

Sediment Size	Observed Diameter (in)	Proposed Diameter (in)
D_{16}	0.4	0.1
D_{50}	1.2	1.2
D_{84}	2.8	2.9
D_{95}	5.0	5.4
D_{100}	21.3	6.0

For sediment mobility, the Modified Critical Shear Stress Approach as described in Appendix E of the US Forest Service (USFS) Guidelines for all systems under 4% was used to analyze mobility for the proposed streambed material at the UNT to Skookum Creek. The sediment mobility analysis indicates all material sizes are anticipated to move at the 2-year flow and higher. The sediment supply within the system appeared to be healthy during the site visit, and it was deemed acceptable to place material that is mobile because the proposed streambed material is very close in size to the observed existing material. See Appendix C for streambed sizing and sediment mobility calculations.

5.2 Channel Complexity

This section describes the channel complexity of the streambed design developed for the UNT to Skookum Creek at MP 5.54.

5.2.1 *Design Concept*

The proposed channel is designed to mimic existing conditions as much as possible by following natural bends and disturbing only the area necessary to adequately tie in to the existing ground and replace the structure under SR 108. LWM will be placed to offer channel-forming features, complexity, and enhanced habitat for fish passage.

The 75th percentile of key piece density per Fox and Bolton (2007) recommends 6 key pieces, 37 total LWM pieces, and 76.2 cubic yards (yd^3) volume for the total 193 LF regraded channel. This percentile of wood placement is suggested to compensate for cumulative deficits of wood loading due to development. A conceptual LWM layout that has been developed for this project area is provided in Figure 66. The conceptual layout proposes 12 key pieces, 37 total LWM pieces, and 84.0 yd^3 volume for the 193-foot-long project reach (including the structure length). The amount of LWM volume exceeds the Fox and Bolton (2007) 75th percentile criterion by 10 percent. At this time, anchoring for key LWM pieces is anticipated but has not been verified with stability calculations.

It is not expected that fish stranding during summer flows will be a risk as the floodplain slopes consistently toward the main channel and does not promote standing water to form within the floodplain of the proposed project extents.

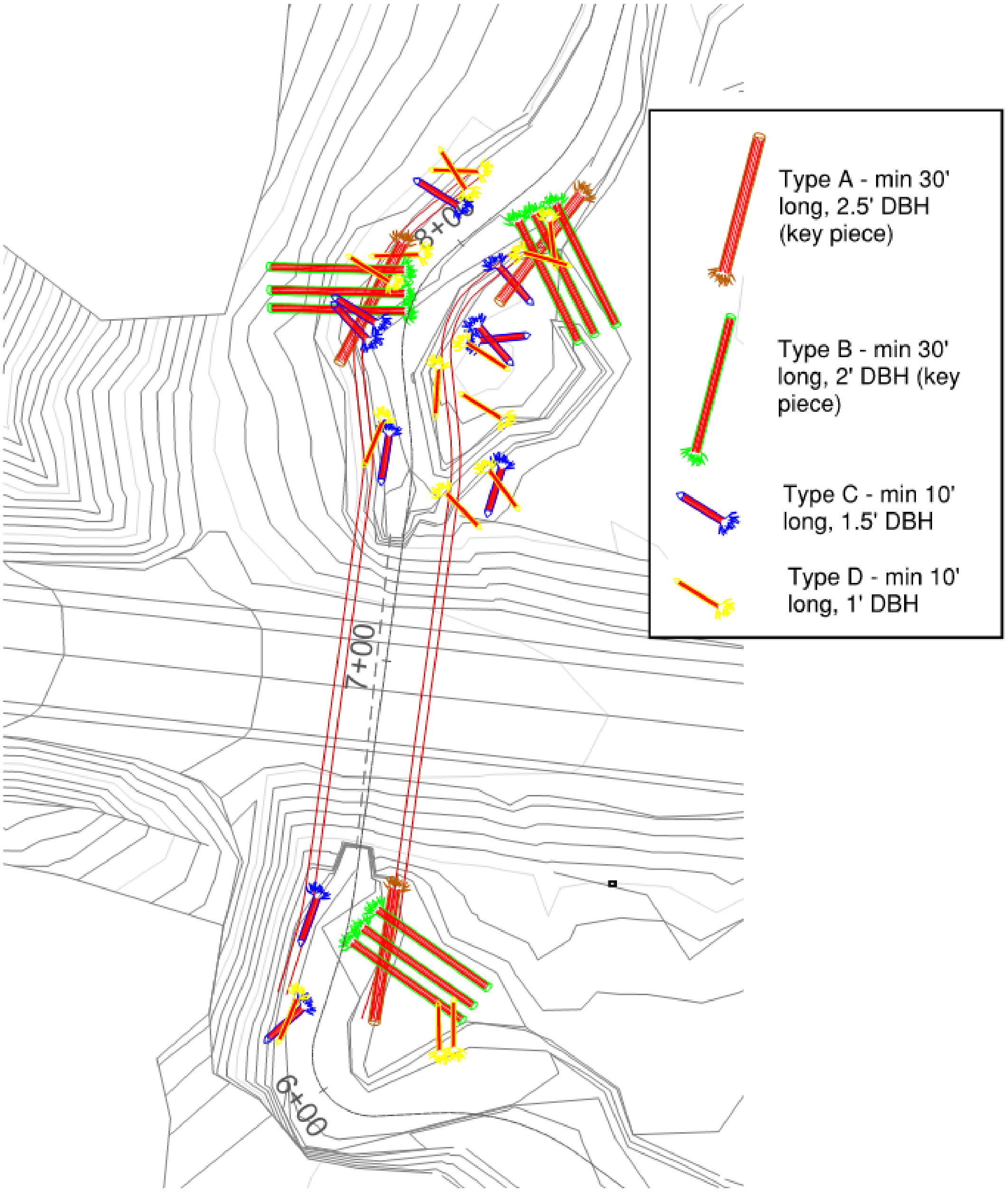

Figure 66: Conceptual layout of habitat complexity

6 Floodplain Changes

This project is not within a mapped floodplain. The pre-project and expected post-project conditions were evaluated to determine whether there would be a change in water surface elevation and floodplain storage.

6.1 Floodplain Storage

Floodplain storage is anticipated to be impacted by the proposed structure. The installation of a larger hydraulic opening will reduce the amount of backwater and associated peak flow attenuation that was being provided by the smaller, existing culvert. A comparison of pre- and post-project peak flow events was not quantified as the models were run with a constant flow rate specified at the upstream boundary of the model.

6.2 Water Surface Elevations

Installation of the proposed structure would eliminate the backwater impacts just upstream of the existing culvert, resulting in a reduction in water surface elevation upstream. The water surface elevation is reduced by as much as 3.5 feet at the inlet of the existing culvert at the 100-year event as shown in Figure 67 and Figure 68. Figure 68 also depicts the extent of backwater that is eliminated.

Immediately downstream of the culvert, channel regrading for proposed conditions causes a rise as much as 0.7 foot in water surface elevation near Station 6+35. The local water surface rise is a result of regrading the channel and removing the debris and sediment that have filled the stream downstream of the existing culvert outlet. Past the outlet, the water surface elevation change varies between no change and a 0.21-foot rise from the existing to proposed conditions.

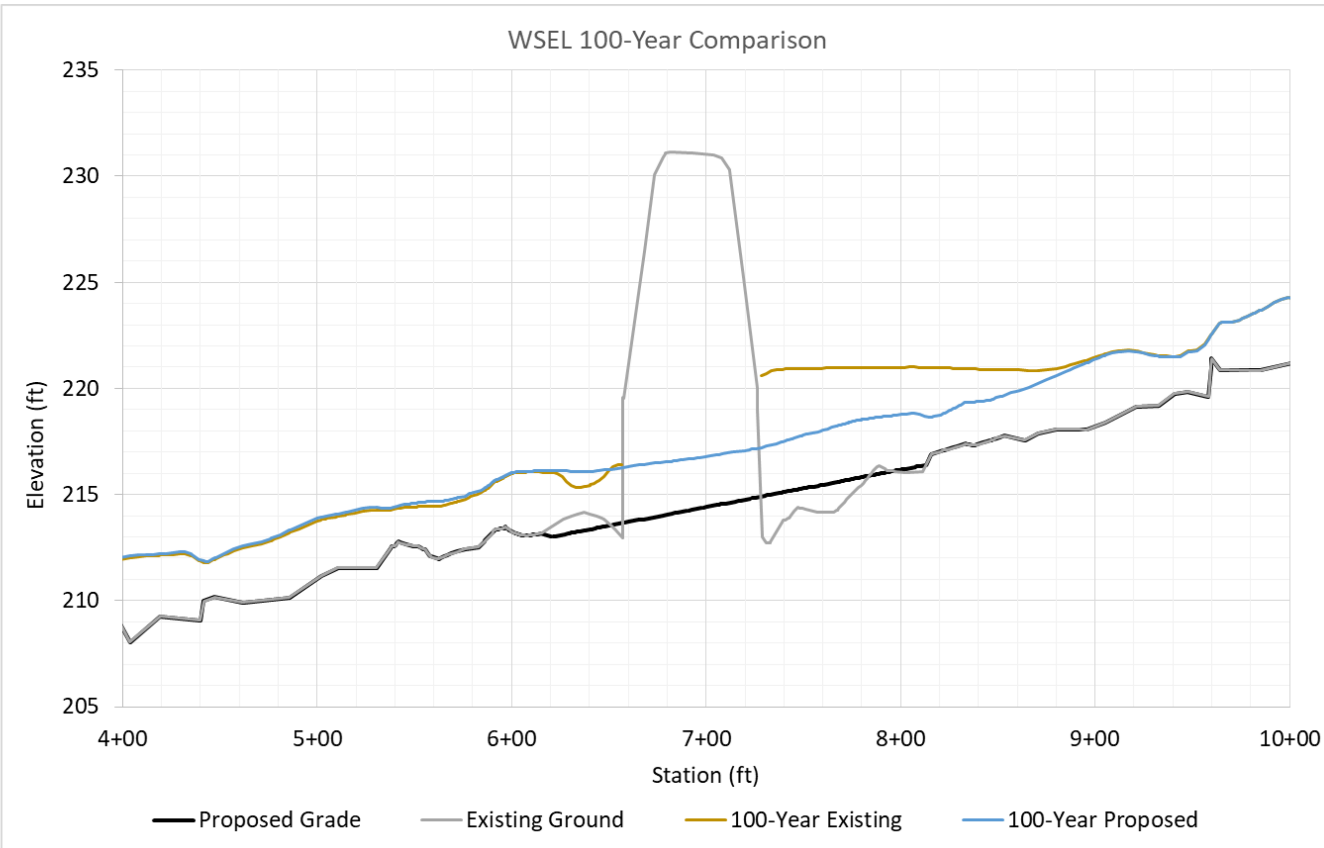

Figure 67: Existing and proposed 100-year water surface profile comparison

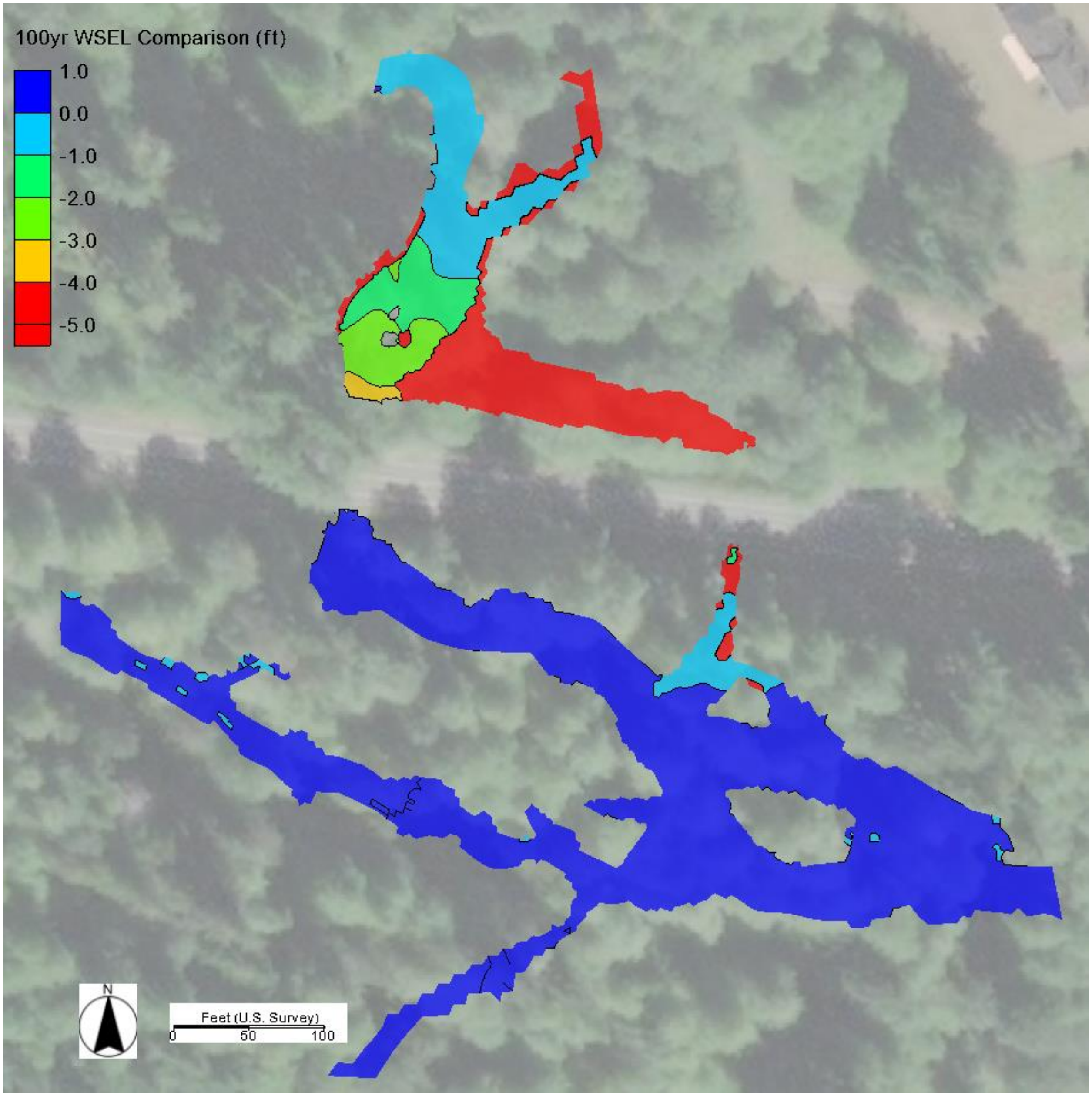

Figure 68: Upstream (left) and downstream (right) water surface elevation change from existing to proposed conditions

7 Climate Resilience

WSDOT recognizes climate resilience as a component of the integrity of its structures and approaches the design of bridges and buried structures through a risk-based assessment beyond the design criteria. For bridges and buried structures, the largest risk to the structures will come from increases in flow and/or sea level rise. The goal of fish passage projects is to maintain natural channel processes through the life of the structure and maintain passability for all expected life stages and species in a system.

7.1 Climate Resilience Tools

WSDOT also evaluates crossings using the mean percent change in 100-year flood flows from the WDFW Future Projections for Climate-Adapted Culvert Design program. All sites consider the 2080 percent increase throughout the design of the structure. Appendix E contains the information received from WDFW for this site.

7.2 Hydrology

For each design WSDOT uses, the best available science is used for assessing site hydrology. The predicted flows are analyzed in the hydraulic model and compared to field and survey indicators, maintenance history, and any other available information. Hydraulic engineering judgment is used to compare model results to system characteristics; if there is significant variation, then the hydrology is reevaluated to determine whether adjustments need to be made, including adding standard error to the regression equation, basin changes in size or use, etc.

In addition to using the best available science for current site hydrology, WSDOT is evaluating the structure at the 2080 predicted 100-year flow event to check for climate resilience. The design flow for the main crossing is 326 cfs at the 100-year storm event. The projected increase for the 2080 flow rate is 10.6 percent, yielding a projected 2080 flow rate of 360.56 cfs. The two other inflow boundary conditions were also increased with the 2080 increased climate change flow. Skookum Creek's 100-year design flow is 191.1 cfs and increased to 211.36 cfs for the 2080 projected flow rate, see Table 4. The Skookum Creek Tributary's 100-year design flow is 51.2 cfs and increased to 56.63 cfs for the 2080 projected flow rate.

7.3 Climate Resilience Summary

A minimum hydraulic opening of 35 feet and a minimum freeboard of 3 feet allows for the channel to behave similarly through the structure as it does in the adjacent reaches under the projected 2080 100-year flow event. This will help to ensure that the structure is resilient to climate change and the system is allowed to function naturally, including the passage of sediment, debris, and water in the future.

8 Scour Analysis

Total scour will be computed during later phases of the project using the 100-year, 500-year, and projected 2080 100-year flow events. The structure will be designed to account for the potential scour at the projected 2080 100-year flow events. For this phase of the project, the risk for lateral migration and potential for degradation are evaluated on a conceptual level. This information is considered preliminary and is not to be taken as a final recommendation in either case.

8.1 Lateral Migration

Lateral migration is expected to be low, but was accounted for with an increase in structure size with the 50 percent Factor of Safety that increased the minimum recommended hydraulic opening from 31 feet to 35 feet. The structure was also not centered on the thalweg and was shifted toward the left floodplain to provide more floodplain conveyance and potential migration.

8.2 Long-term Aggradation/Degradation of the Riverbed

The proposed stream will be graded at a similar slope to the existing stream reference reach. It is anticipated that aggradation or long-term degradation will be less than 1 foot for either if it does occur. LWM will also help in avoiding aggradation and degradation by providing channel complexity.

Summary

Table 14: Report summary

Stream Crossing Category	Elements	Values	Report Location
Habitat gain	Total length	1,600'	
Bankfull width	Average BFW	23.5'	2.8.2 Channel Geometry
	Reference reach found?	Y	2.8.1 Reference Reach Selection
Channel slope/gradient	Existing crossing	-0.2%	2.8.4 Vertical Channel Stability
	Reference reach	2.1%	2.8.2 Channel Geometry
	Proposed	1.7%	4.4.2 Channel Planform and Shape
Countersink	Proposed	FHD	4.7.3 Freeboard
	Added for climate resilience	FHD	4.7.3 Freeboard
Scour	Analysis	See link	8 Scour Analysis
	Streambank protection/stabilization	See link	8 Scour Analysis
Channel geometry	Existing	23.5' BFW	2.8.2 Channel Geometry
	Proposed	35' structure	4.4.2 Channel Planform and Shape
Floodplain continuity	FEMA mapped floodplain	N	6 Floodplain Changes
	Lateral migration	Y/N	2.8.5 Channel Migration
	Floodplain changes?	Y	6 Floodplain Changes
Freeboard	Proposed	At least 3'	4.7.3 Freeboard
	Added for climate resilience	Y	4.7.3 Freeboard
	Additional recommended	0.1'	4.7.3 Freeboard
Maintenance clearance	Proposed	5.7'	4.7.3 Freeboard
Substrate	Existing	D_{50} = 1.2"	2.8.3 Sediment
	Proposed	D_{50} = 1.2"	5.1 Bed Material
Hydraulic opening	Proposed	35'	4.7.2 Minimum Hydraulic Opening Width and Length
	Added for climate resilience	N	4.7.2 Minimum Hydraulic Opening Width and Length
Channel complexity	LWM	Y	5.2 Channel Complexity
	Meander bars	N	5.2 Channel Complexity
	Boulder clusters	N	5.2 Channel Complexity
	Mobile wood	Y	5.2 Channel Complexity
Crossing length	Existing	72' long structure	2.7.2 Existing Conditions
	Proposed	193' total regrade	4.7.2 Minimum Hydraulic Opening Width and Length
Floodplain utilization ratio	Flood-prone width	66'	4.2 Existing-Conditions Model Results
	Average FUR upstream and downstream	2.8	4.2 Existing-Conditions Model Results
Hydrology/design flows	Existing	See link	3 Hydrology and Peak Flow Estimates
	Climate resilience	See link	3 Hydrology and Peak Flow Estimates
Channel morphology	Existing	See link	2.8.2 Channel Geometry
	Proposed	See link	5.2 Channel Complexity
Channel degradation	Potential?	N	8.2 Long-term Aggradation/Degradation of the Riverbed
	Allowed?	Y	8.2 Long-term Aggradation/Degradation of the Riverbed
Structure type	Recommendation	N	4.7.1 Structure Type
	Type	N/A	4.7.1 Structure Type

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Appendices

Appendix A: Hydraulic Field Report Form

WSDOT Hydraulics Section	Hydraulics Field Report	Project Number:
	Project Name: SR 108 MP 5.54 UNT Skookum (WDFW 990385)	Date: 1) January 21, 2020 2) March 6, 2020
	Project Office: Olympia Project Engineers Office	Time of Arrival: 2) 11:30 AM
	Location: UNT Skookum SR 108 MP 5.54	Time of Departure: 2) 1:00 PM
Purpose of Visit: Site Reconnaissance	Weather:	Prepared By: Doran

Meeting Location:
UNT Skookum Creek, Mason County, SR 108 MP 5.54

Attendance List:

Name	Organization	Role
First Visit (1/21/2020)		
Shaun Bevan	HDR	Water Resource Engineer
Grace Doran	HDR	Water Resource EIT
Ian Welch	HDR	Biologist
Second Visit- Stakeholder Reconnaissance (3/6/2020)		
Brett Boogerd	WSDOT	Engineer
Cliff Mansfield	WSDOT	Consultant
Sarah Zaniewski	Squaxin Tribe	Biologist
Pad Smith	WDFW	Habitat Engineer
Dave Collins	WDFW	Habitat Biologist
Beth Rood	HDR	Hydraulics Lead
Paul Ferrier	HDR	Project Manager
Grace Doran	HDR	Water Resource EIT
Lisa Danielski	HDR	Senior Environmental Scientist

Bankfull Width:

Describe measurements, locations, known history, summarize on site discussion

HDR conducted an independent site visit on January 21, 2020 prior to the stakeholder meeting to measure bankfull width, collect pebble count data, and locate a reference reach. HDR walked the stream approximately 300 feet upstream and approximately 700 feet downstream of the existing 6' span concrete box culvert crossing. HDR took eight bankfull width measurements upstream and downstream of the crossing. See Figure 1 for measurement locations.

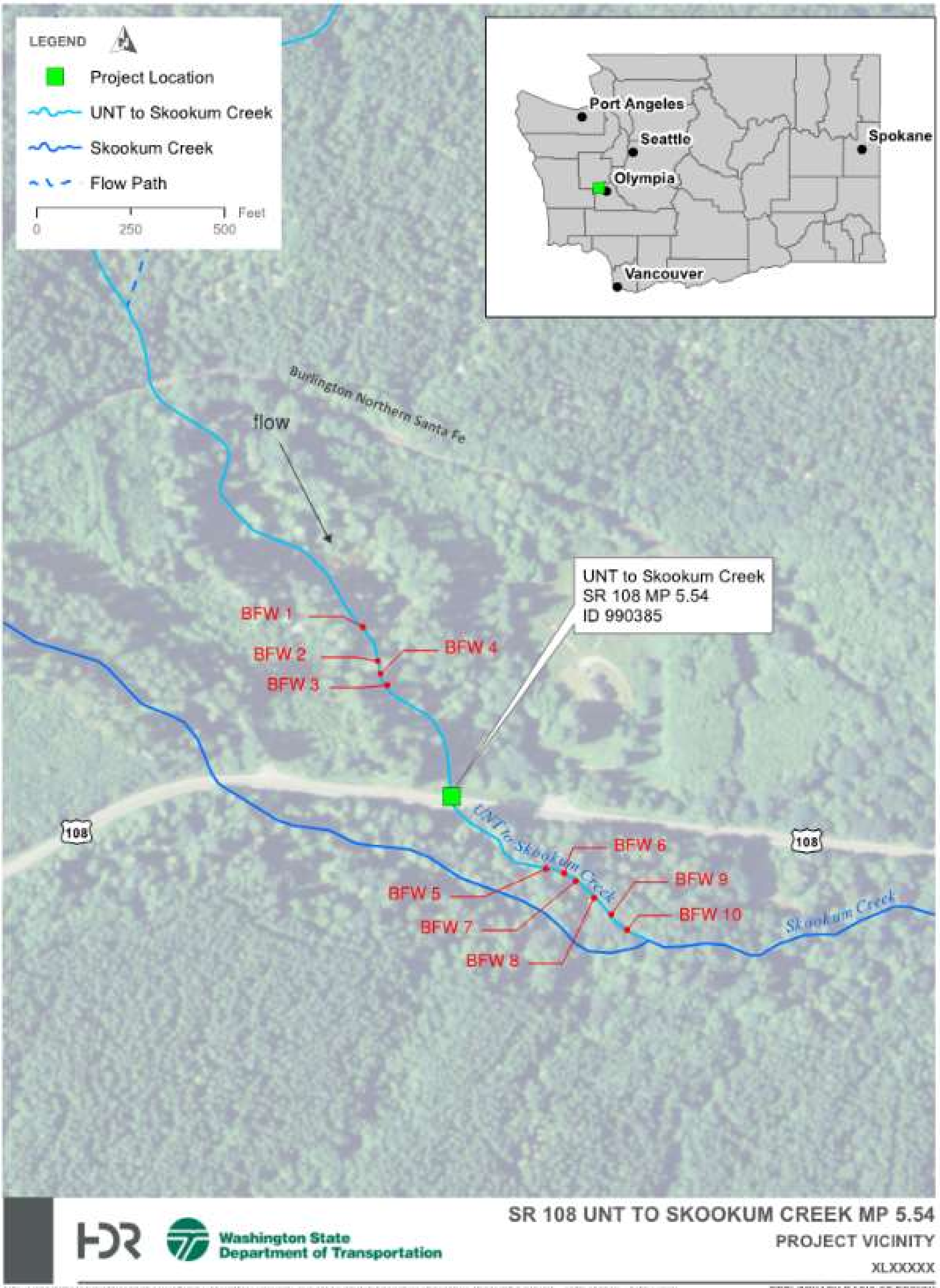


Figure 1 - Bankfull width measurements and pebble count locations

During the stakeholder meeting on March 6th, 2020, HDR, WDFW, WSDOT and a Squaxin Tribal representative agreed on including two more bankfull widths, and removing two, resulting in an average **design bankfull width of 23.5 feet** for design. The eight previously measured widths were remeasured and confirmed, see table 1 below.

Table 1 Bankfull Width Measurements

BFW #		Width	Included in Design AVG?	Concurrence Notes
Regression Eqn		17.8 ft	No	
US	1	16.0 ft	No	Removed from design average 3/6/2020
	2	21.0 ft	Yes	WDFW/Tribe concurred
	3	25.5 ft	Yes	WDFW/Tribe concurred
	4	29.0 ft	Yes	Added by WDFW 3/6/2020
DS	5	19.3 ft	No	Removed from design average 3/6/2020
	6	20.0 ft	Yes	Added by WDFW 3/6/2020
	7	23.0 ft	Yes	WDFW/Tribe concurred
	8	21.5 ft	Yes	WDFW/Tribe concurred
	9	21.0 ft	Yes	WDFW/Tribe concurred
	10	26.0 ft	Yes	WDFW/Tribe concurred
Design Average		**23.5 ft**		

Reference Reach:

Describe location, known history, summarize on site discussion, appropriateness, bankfull measurement

A reference reach was selected between the bankfull width measurement locations downstream. However, there was another location upstream that could be used if the design slope was closer to the bankfull measurements collected upstream. Both reaches appeared to be natural and not manipulated. A pebble count was also conducted in both locations. These reaches will be used to help guide the design of the channel shape. Conversations in the field with the Squaxin tribe indicated this area is critical to provide adequate rearing for Coho which thrive in colder temperatures provided by the canopy cover within this reach. There is a full barrier approximately 1,500 feet upstream of the SR 108 crossing at the BNSF railroad crossing.

Data Collection:

Describe who was involved, extents collection occurred within

HDR conducted an independent site visit on January 21, 2020 prior to the stakeholder site meeting. HDR walked the stream approximately 300 feet upstream and approximately 700 feet downstream of the existing culvert crossing. HDR took eight bankfull width measurements approximately upstream and downstream of the culvert crossing.

HDR, WDFW, WSDOT, and a Squaxin tribal representative conducted a stakeholder meeting on March 6, 2020 to discuss preliminary hydraulic design criteria and gain concurrence on bankfull width.

Observations:

Describe site conditions, channel geomorphology, habitat type and location, flow splits, LWM location and quantity, etc.

Upstream Reach

The upstream reach of the UNT has consistently vegetated banks with wooded floodplains, there is large woody material present and some riffles in varying stages throughout the channel. The reach substrate is consistently gravel and small cobbles. Beginning approximately 300’ upstream of the crossing, the UNT passes through riffles before taking a rough 75 degree right turn over a fallen wood acting as a weir spanning the entire channel creating an approximate 2’ hydraulic drop. Directly downstream of the drop, the right banks are slightly undercut at 2-3’ high and there is woody material on the left banks at 2-3’ high as the channel takes a slight right turn. After the bend, the channel remains fairly straight with the thalweg generally keeping to the left side of the channel, see Figure 4.

Continuing down the mainstem of the Tributary, the left banks are about 2’ high and the right banks 3’ high with a small gravel bar in the middle of the channel. There is a fallen tree over the channel that divides the slope of the channel, see Figure 3. Upstream, the channel is fairly shallow, and downstream the channel is much steeper as it approaches the culvert. There is a side channel that begins approximately 150’ upstream of its outfall to the Tributary at the culvert inlet. There is no upstream connection to the Tributary. It meanders 30-50’ to the left of the Tributary until stagnating at a large pool directly upstream of the outfall. Going into the culvert, the channel is steep with angular material within the channel and heavy rip rap on the 7’ high right banks. The side channel outfalls to the left of the culvert inlet. The 6’ span concrete box culvert has an exposed bottom with 45 degree wingwalls, see Figure 2.

Downstream Reach

The downstream reach remains fairly vegetated with woody material providing habitat within the stream. The channel substrate is consistently gravel and small cobbles. The Tributary meanders roughly 700’ until reaching the confluence with Skookum Creek. The culvert outlet has concrete wingwalls with 45 degree angles. The bottom is not exposed and there is natural material present, see Figure 6. At the culvert outlet there is a larger pool due to deadfall trees from the highly eroded right bank. There are some riffles beneath the trees as the channel moves slightly to the right, see Figure 7.

Continuing downstream there is woody material within the stream that has rerouted the direction of the channel. The wood has helped accumulate smaller wood, sediment, gravel and sandy substrate. This obstruction has confined the channel to the right at a 90 degree bend, and has created an eroded right bank that sit roughly 5’ tall, see Figure 8. Downstream of the bend the channel meanders slightly to the left. From this point on, the banks remain vegetated and are not as eroded compared to the immediate upstream reach. There is a large downed tree acting as a weir that spans the channel and creates a 1’ hydraulic drop as the channel bends to the right. Downstream of the weir there is woody material on both the left and right side of the channel.

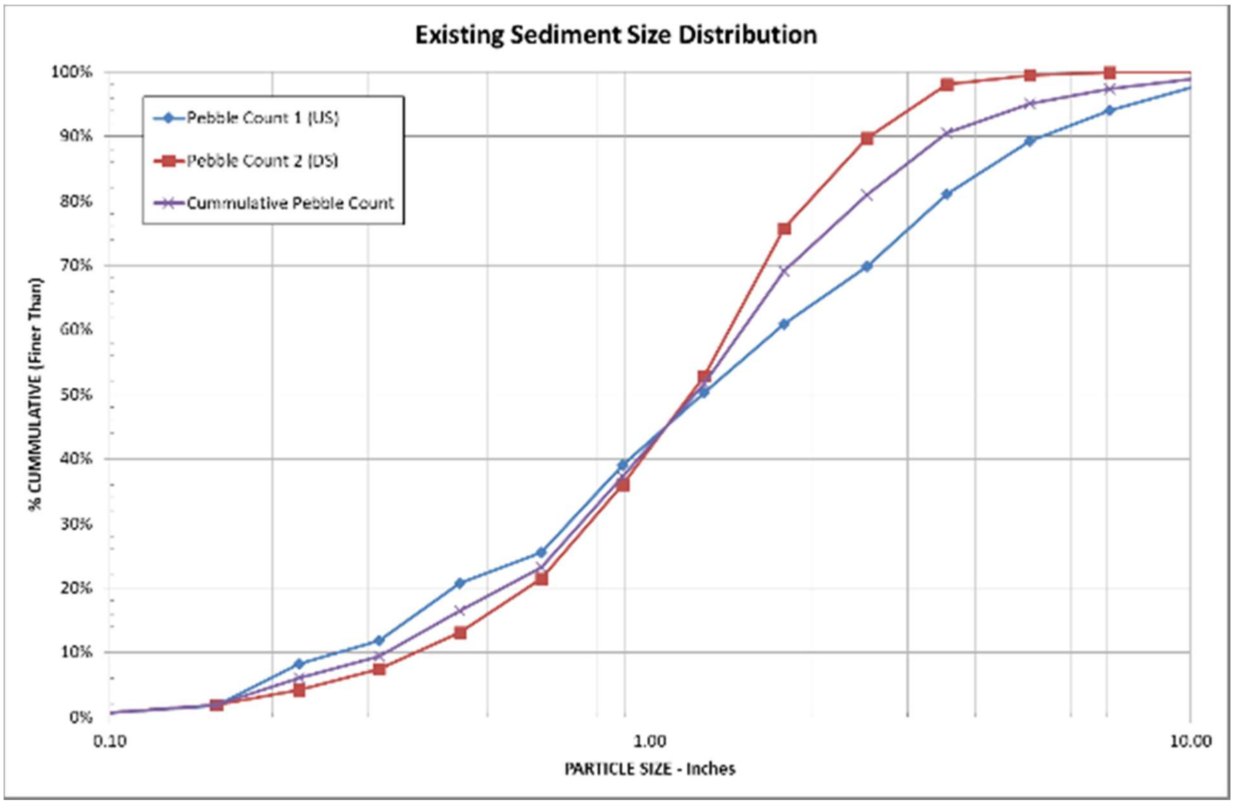
The Tributary continues along a straight path for approximately 50-60’ until reaching a log jam that spans almost the whole channel. It consists of 1-2 downed trees along with woody material that has accumulated on the jam, see Figure 9. The Tributary continues roughly 50’ to the confluence with Skookum Creek, which joins on the right bank, see Figure 10. Approximately 20’ downstream of the confluence there is another log jam that has accumulated woody material and spans the entire channel.

Pebble Counts/Sediment Sampling:

Describe location of sediment sampling and pebble counts if available

Two pebble counts were performed, one on the upstream and one on the downstream side. The upstream pebble count was taken in between bankfull measurements 2 and 3, and the downstream pebble count was taken in between bankfull measurements 7, 8, and 9. The cumulative distribution and specific pebble sediment sizes are provided in the following chart and table.

During the stakeholder meeting, it was decided streambed sediment with a mixture of WSDOT cobbles would be used as to mimic the existing streambed material.



Particle	Upstream Observed Material Diameter (in)	Downstream Observed Material Diameter (in)	Cumulative Material Diameter (in)
D_{15}	0.36	0.48	0.41
D_{35}	0.80	0.87	0.84
D_{50}	1.25	1.18	1.21
D_{84}	4.01	2.18	2.81
D_{95}	7.76	3.12	5.02

Photos:

Any relevant photographs listed above

Figure 2 - Culvert inlet


Figure 3 – Upstream of the fallen tree, looking downstream


Figure 4 – Straight run looking upstream

Figure 5 - Upstream bankfull width measurement location

Figure 6 - Culvert outlet

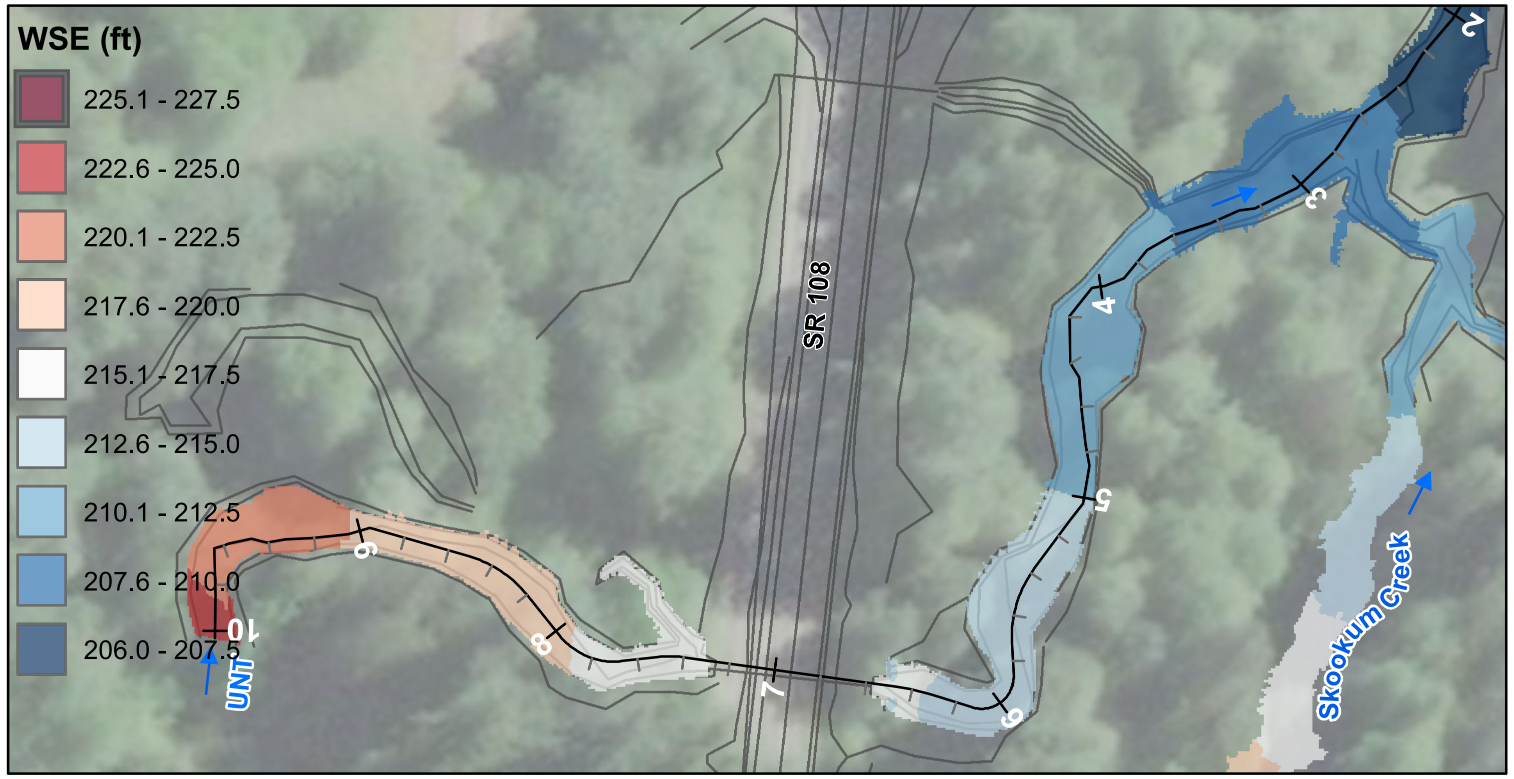
Figure 7 - View from the left bank at the culvert outlet looking downstream

Figure 8 – Looking downstream at right 90 degree turn

Figure 9 – Looking downstream at the log jam

Figure 10 – Looking upstream at the confluence of Skookum Creek and the tributary

Appendix B: SRH-2D Model Results



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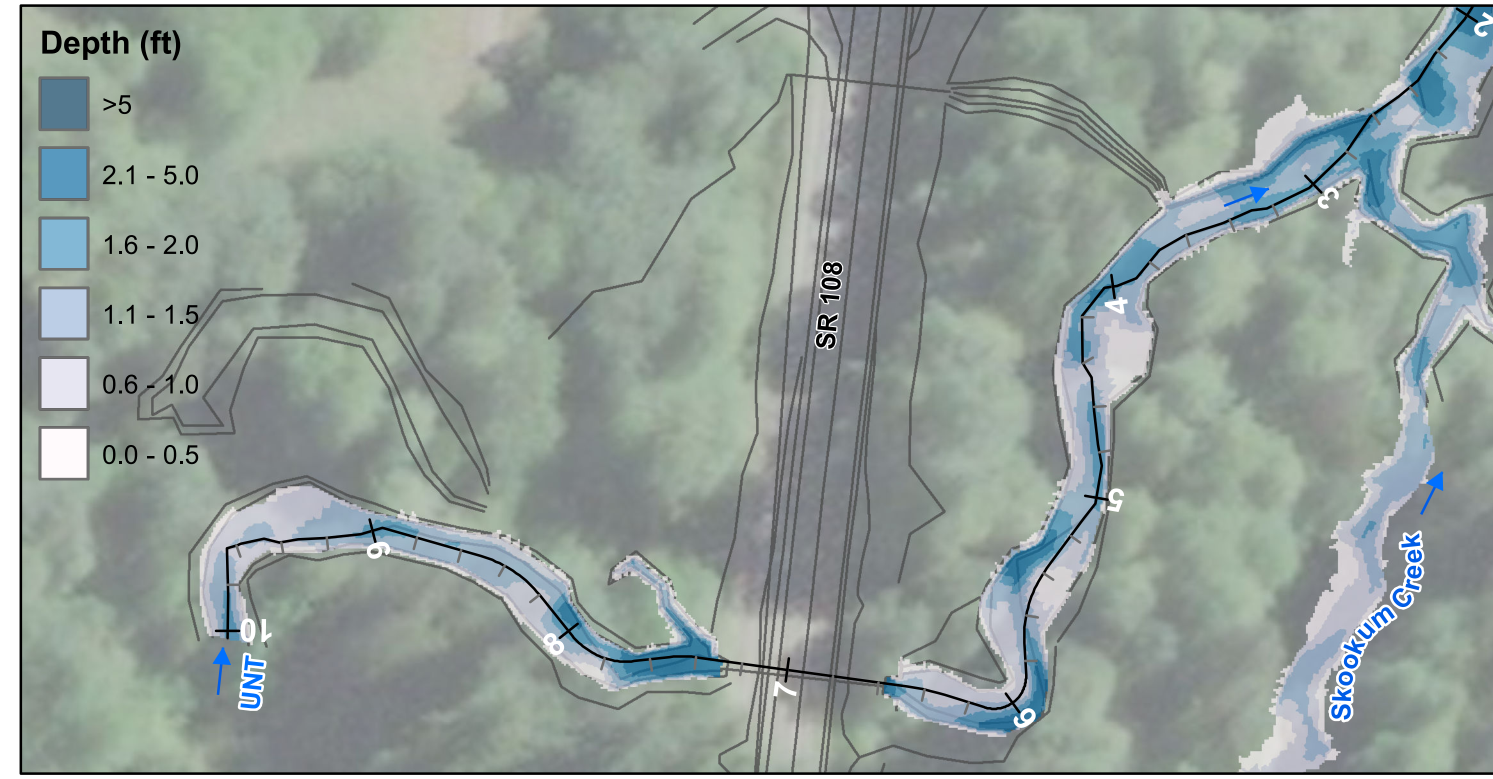

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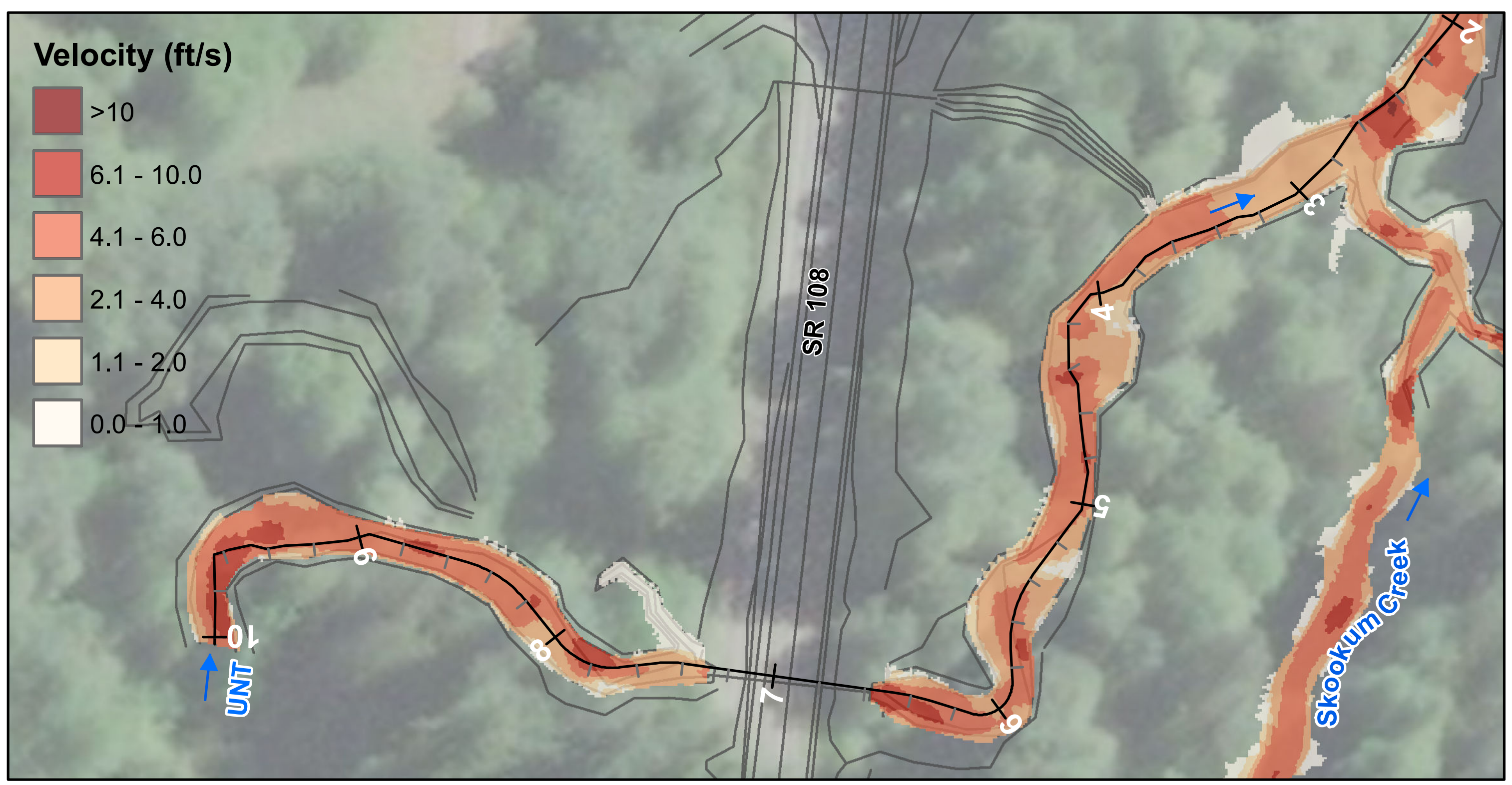

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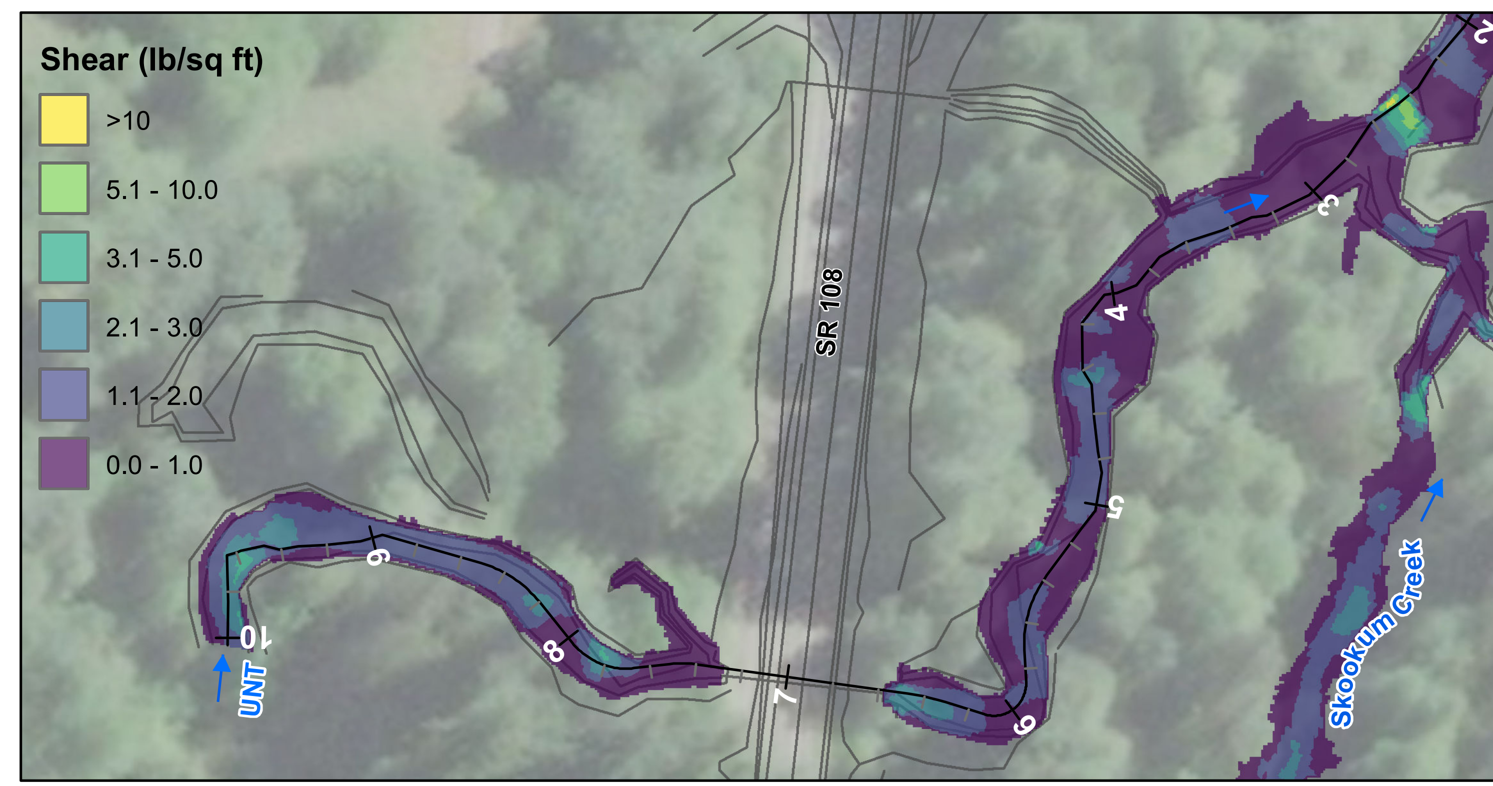

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Washington State Department of Transportation

EXISTING CONDITIONS 2-YEAR

SR 108 UNNAMED TRIBUTARY TO SKOOKUM CREEK
MP 5.54

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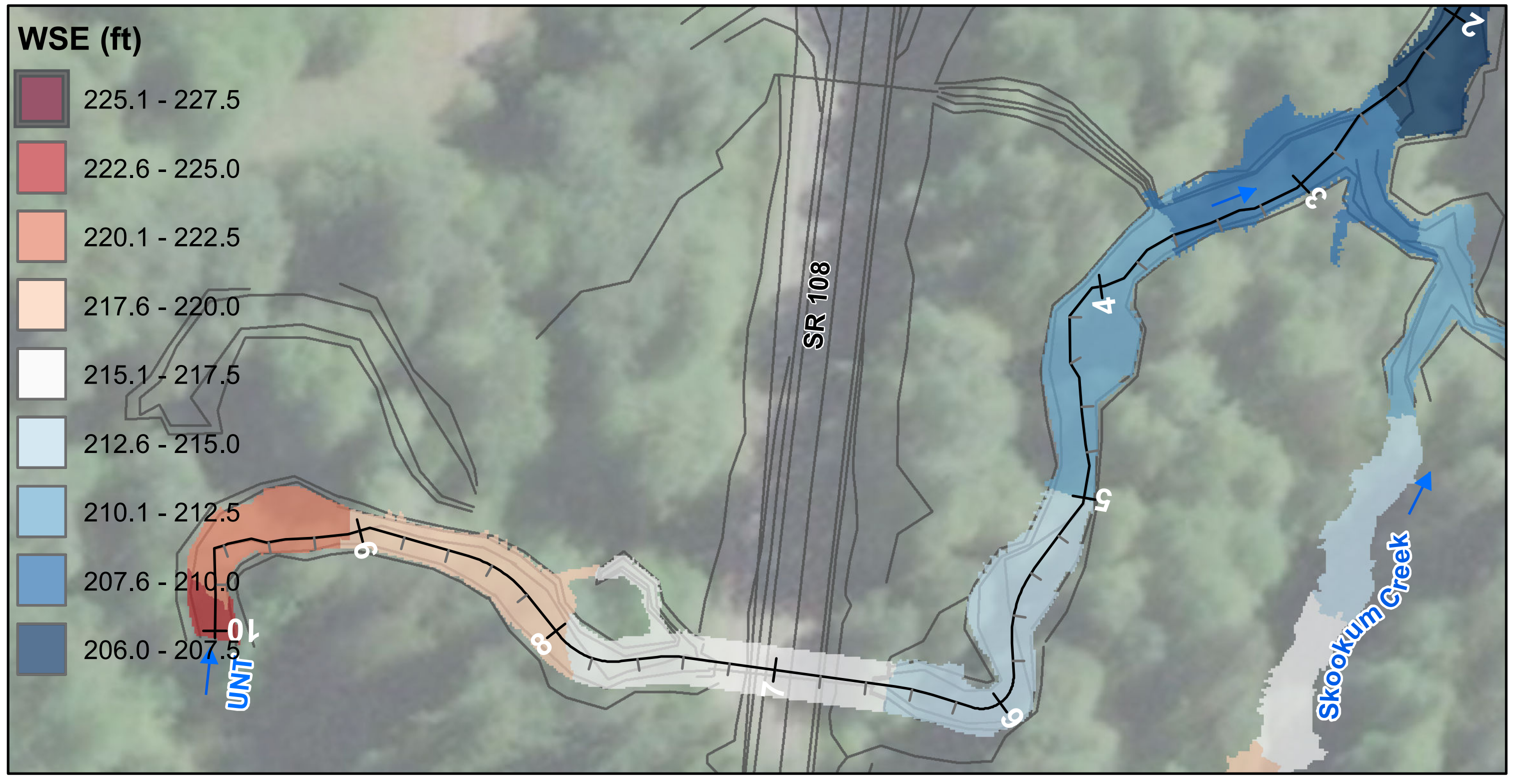

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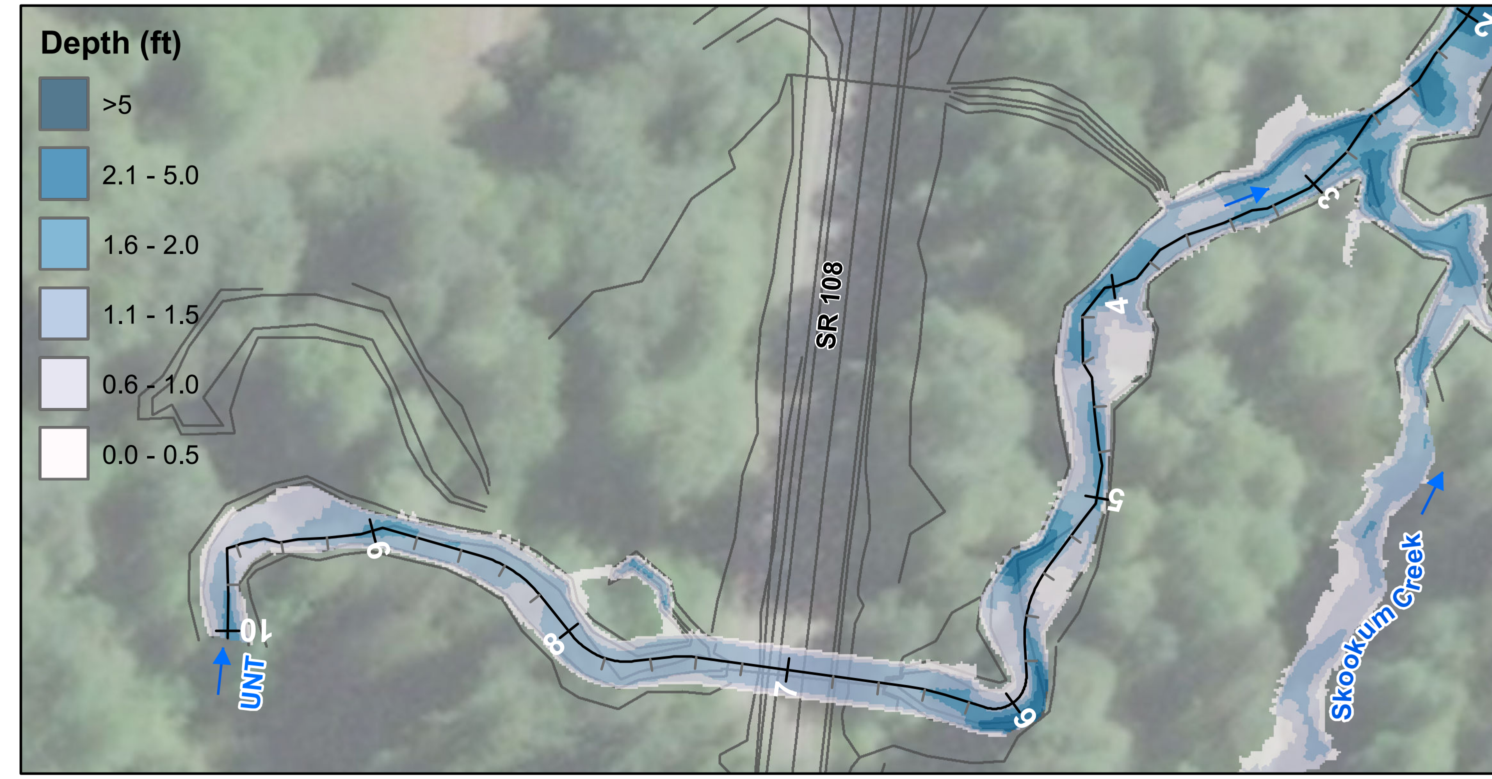

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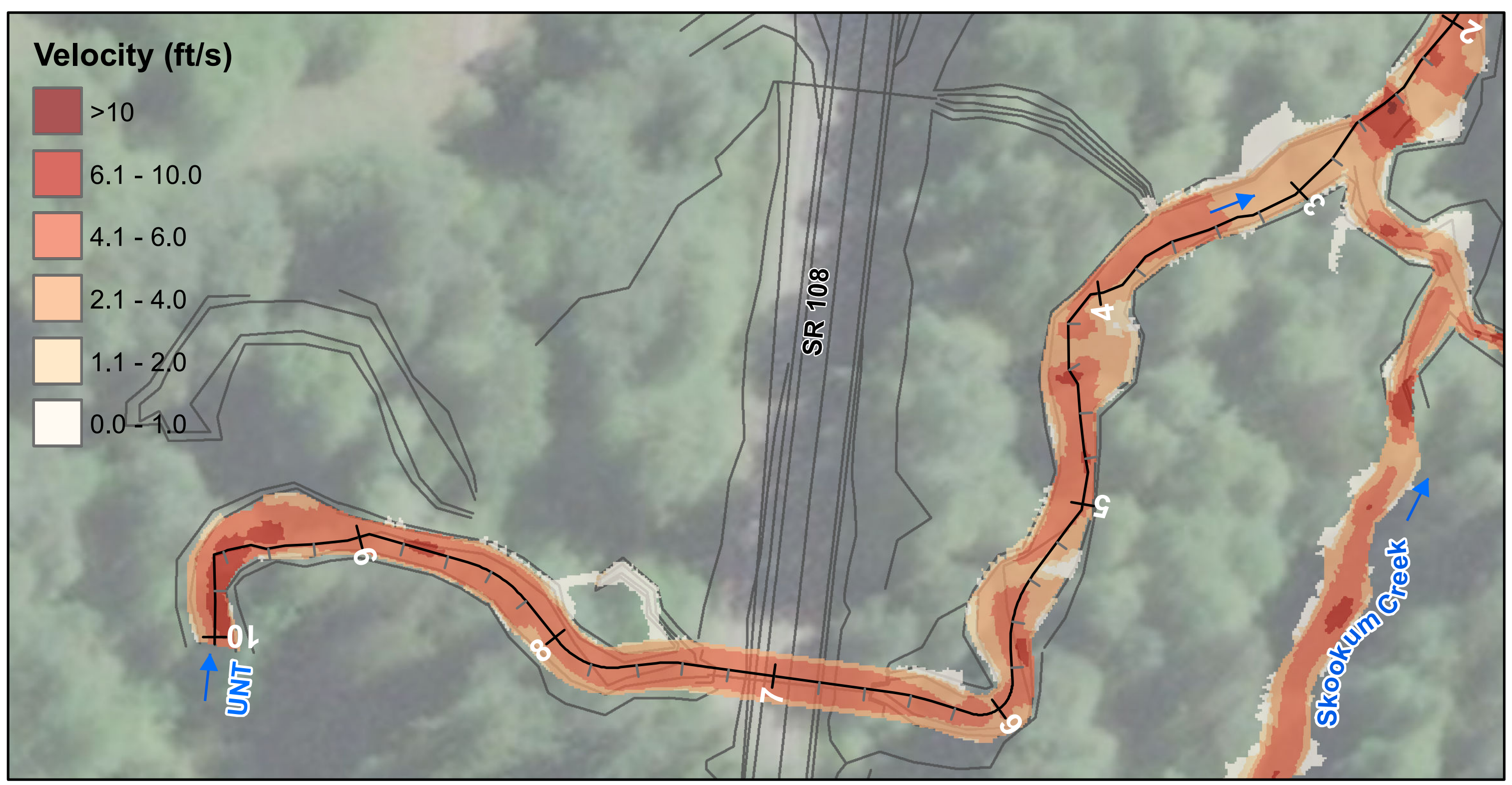

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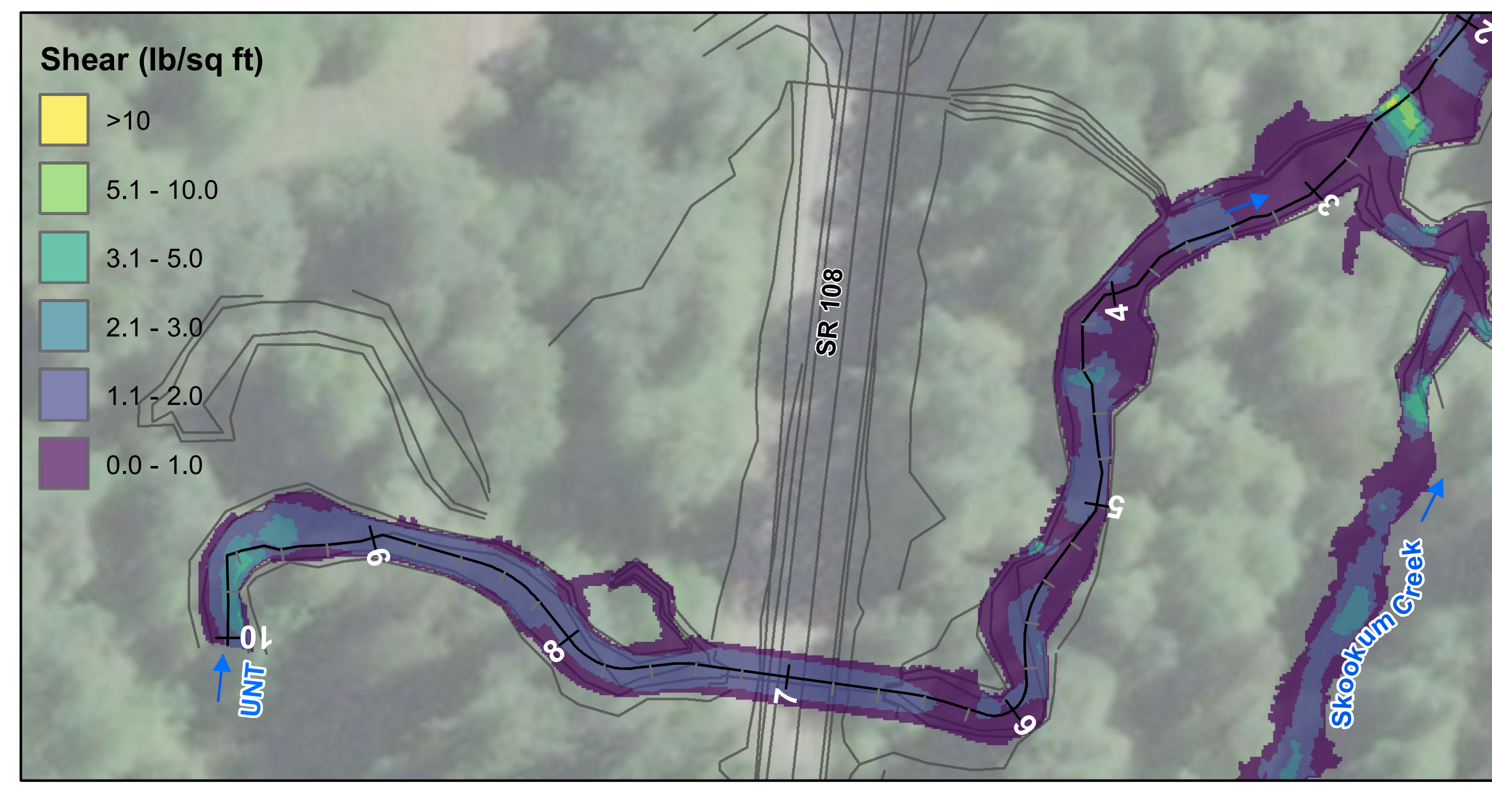

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Washington State Department of Transportation

PROPOSED CONDITIONS 2-YEAR

SR 108 UNNAMED TRIBUTARY TO SKOOKUM CREEK
MP 5.54

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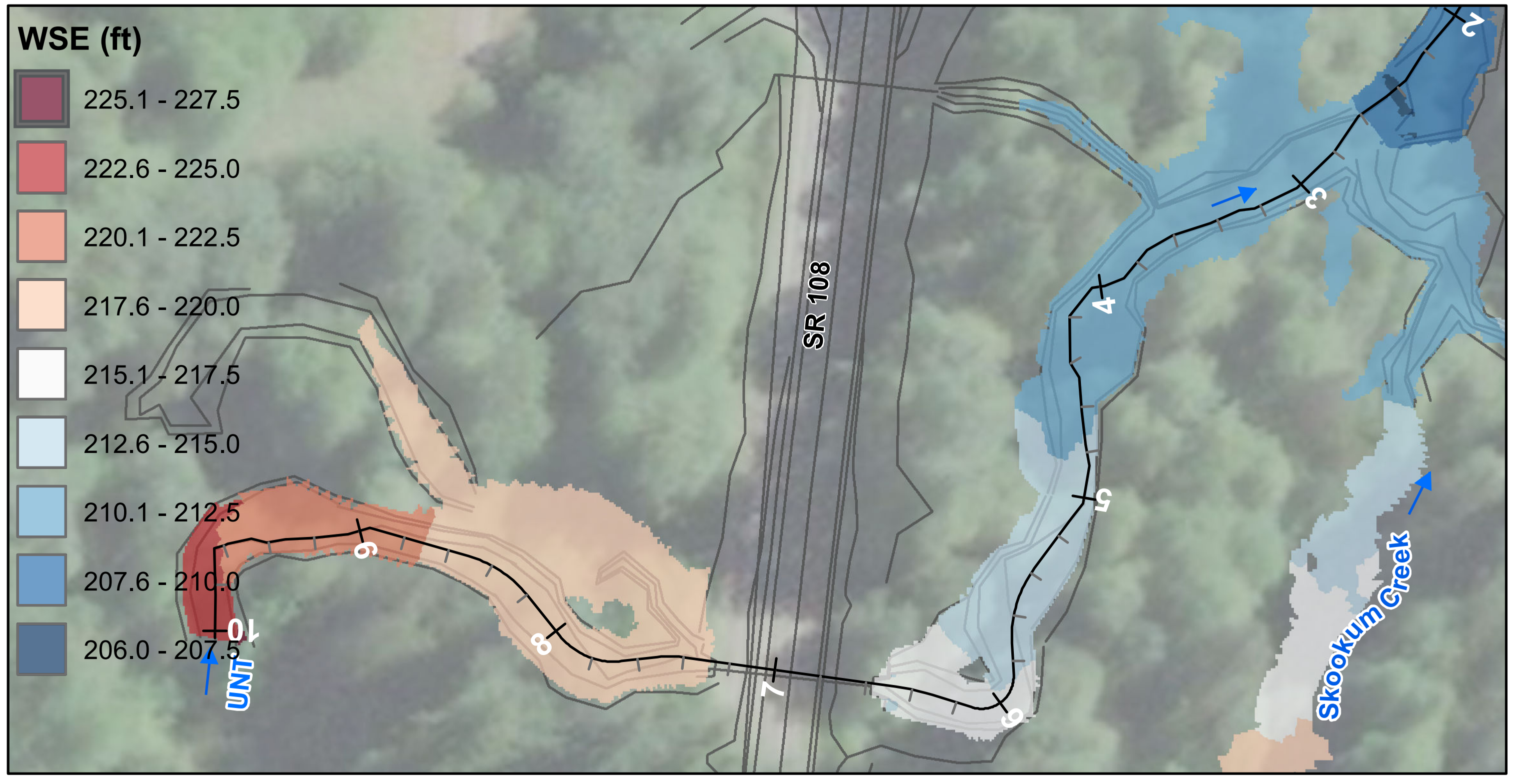

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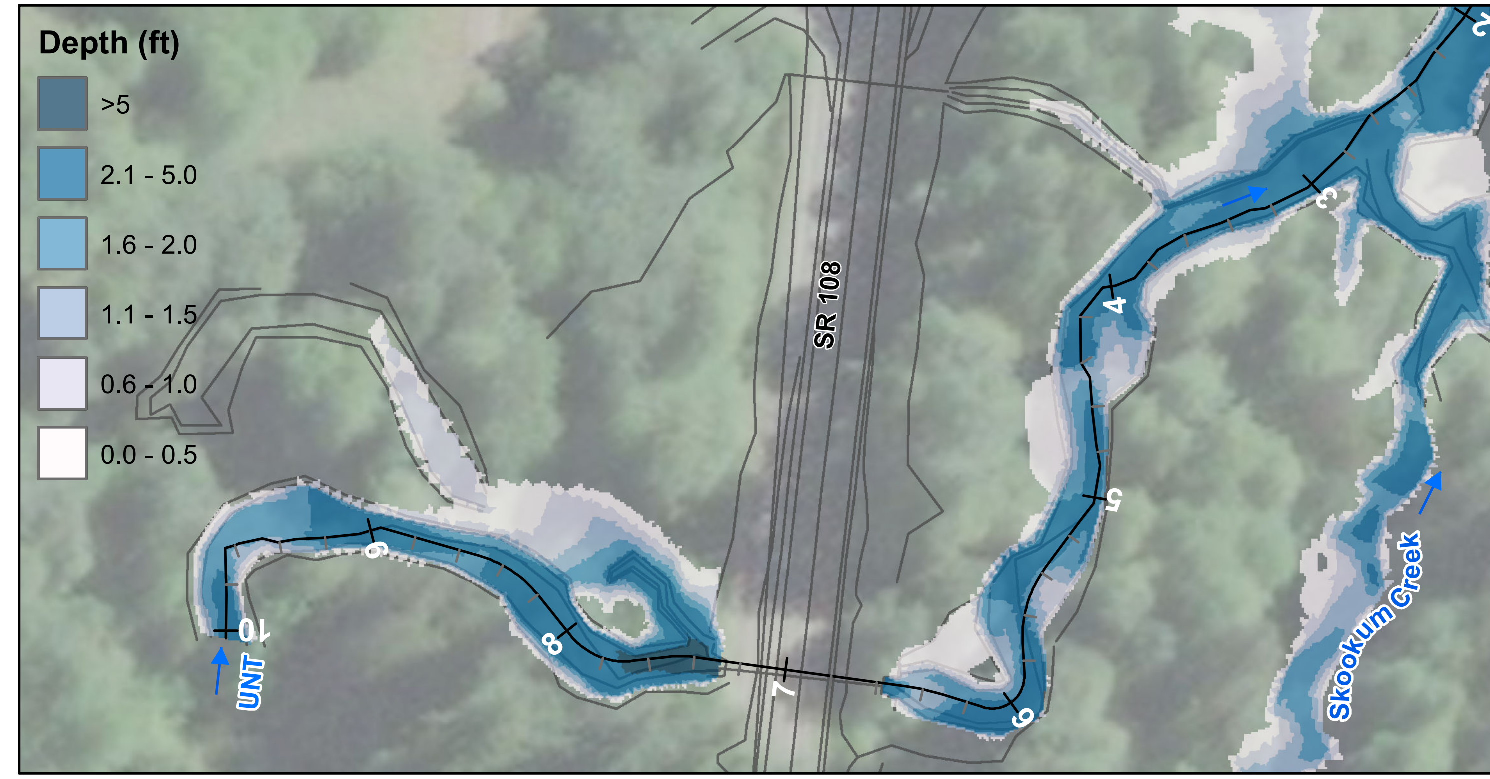

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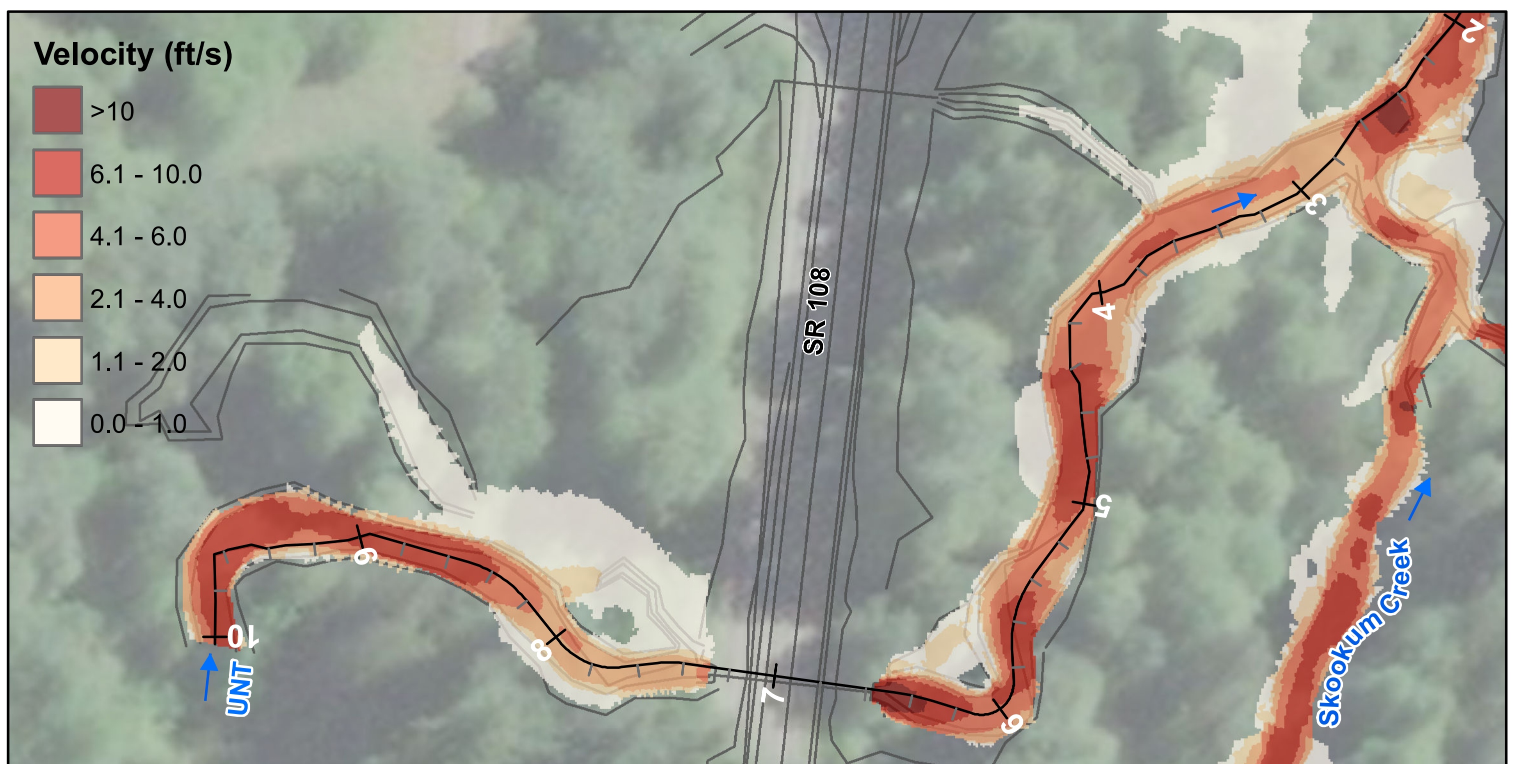

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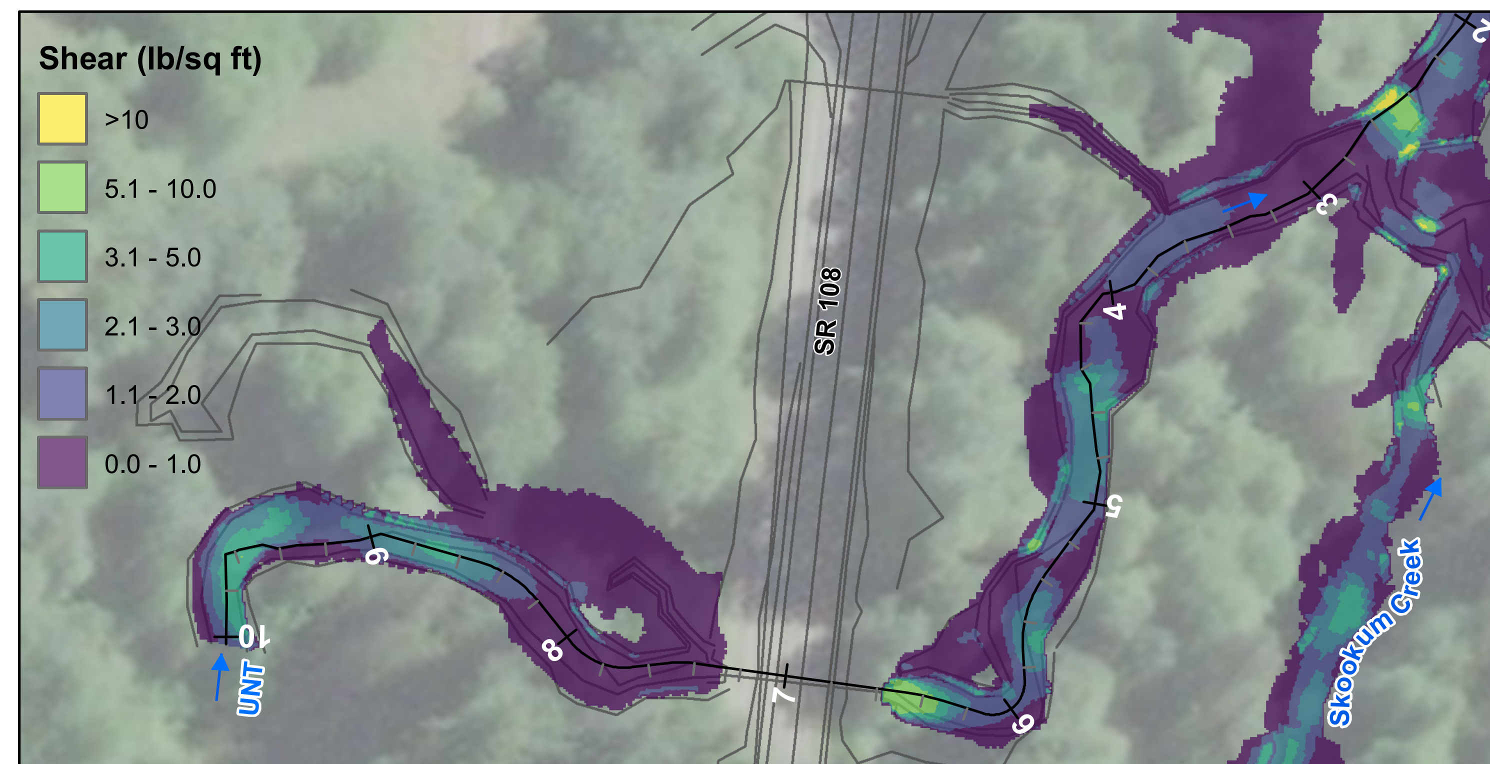

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Washington State Department of Transportation

EXISTING CONDITIONS 25-YEAR

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MP 5.54

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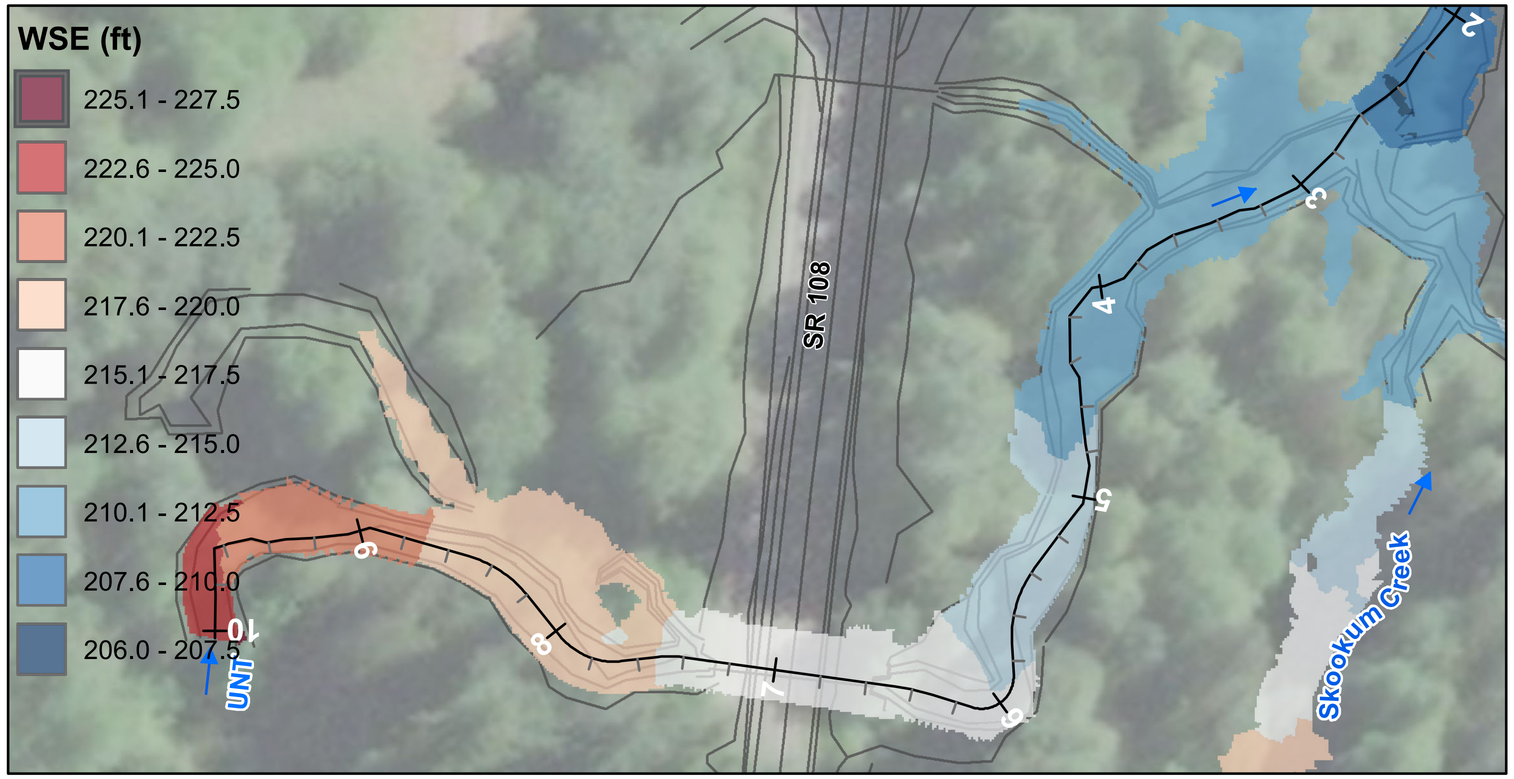

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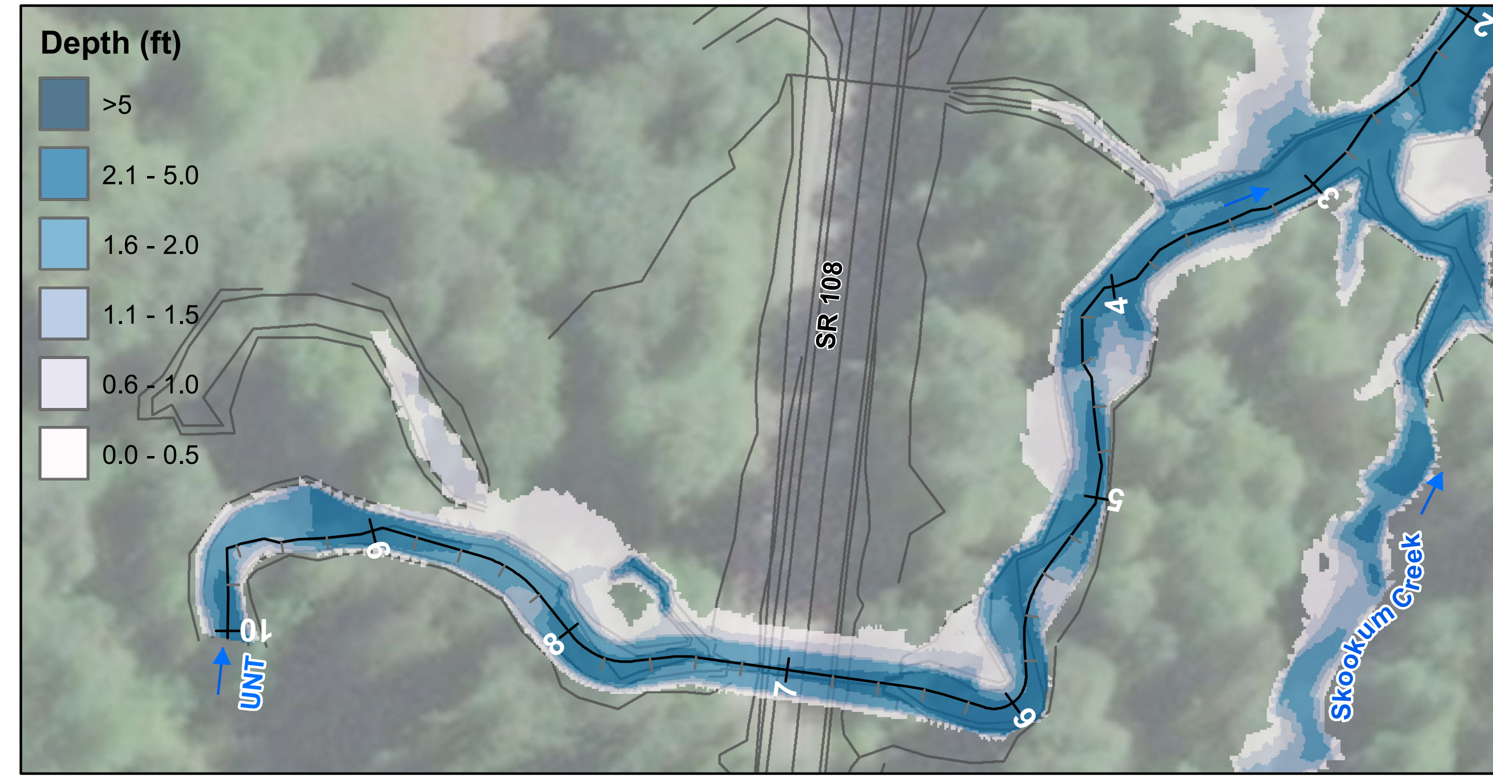

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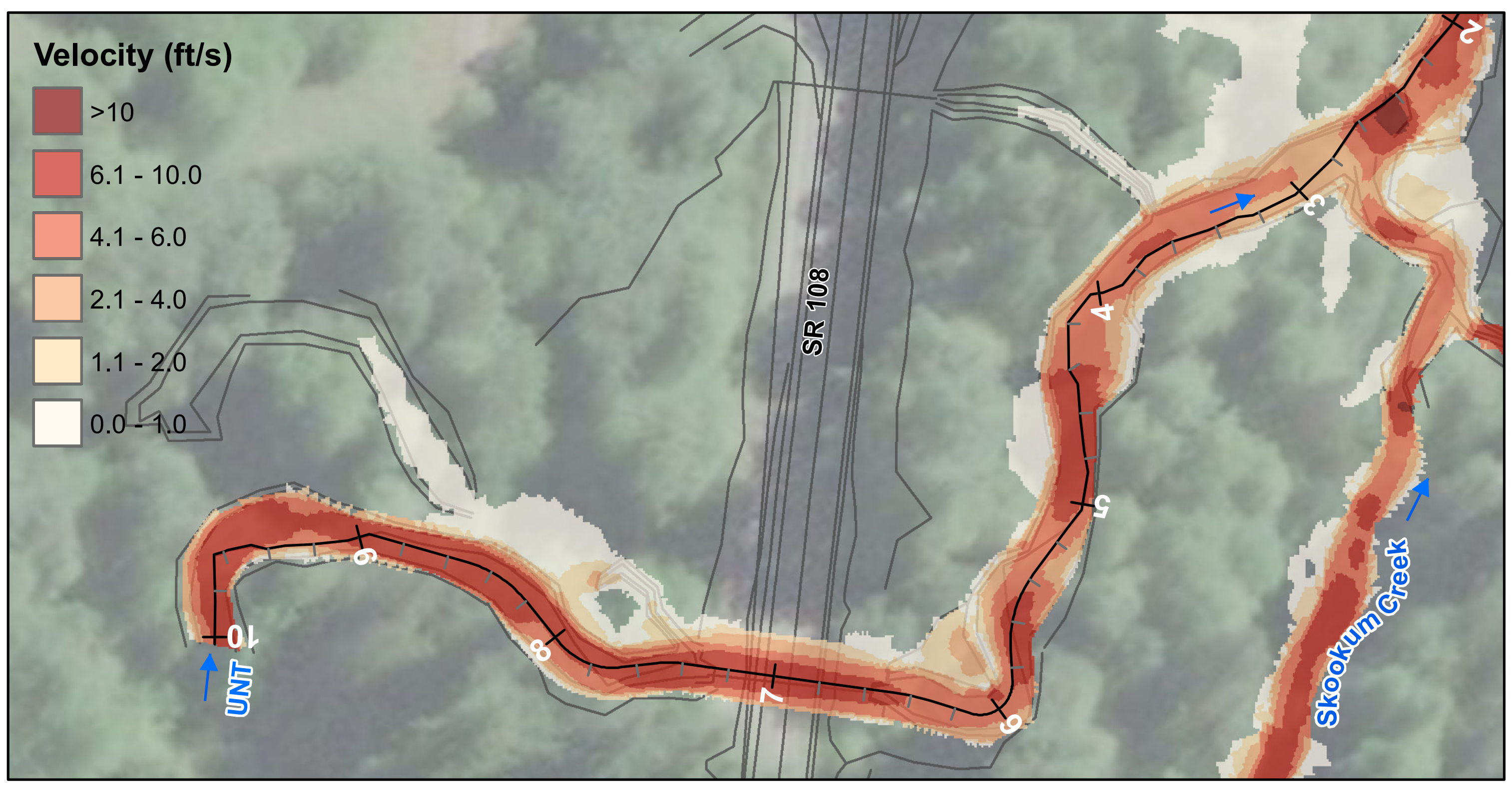

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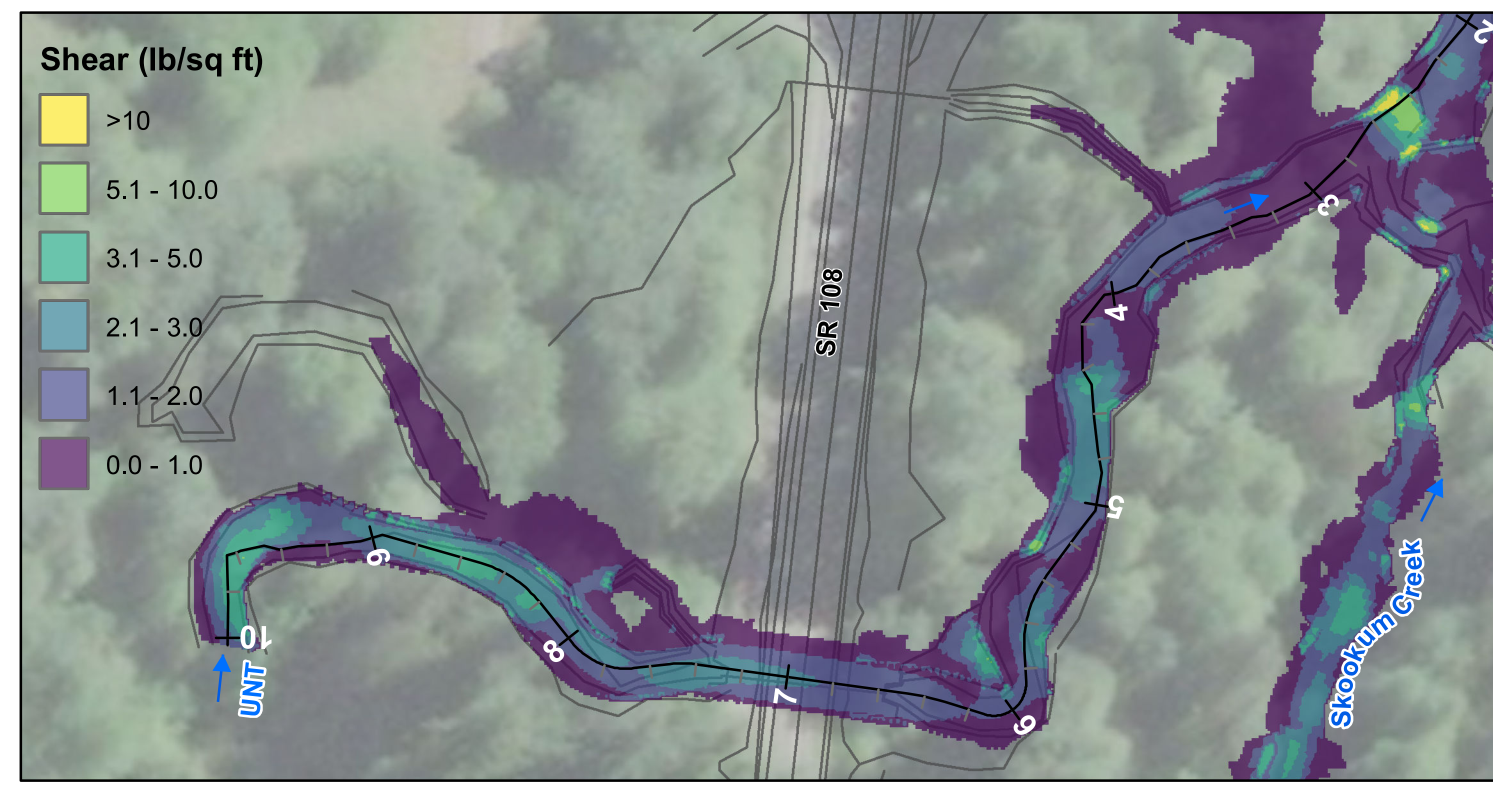

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Washington State Department of Transportation

PROPOSED CONDITIONS 25-YEAR

SR 108 UNNAMED TRIBUTARY TO SKOOKUM CREEK
MP 5.54

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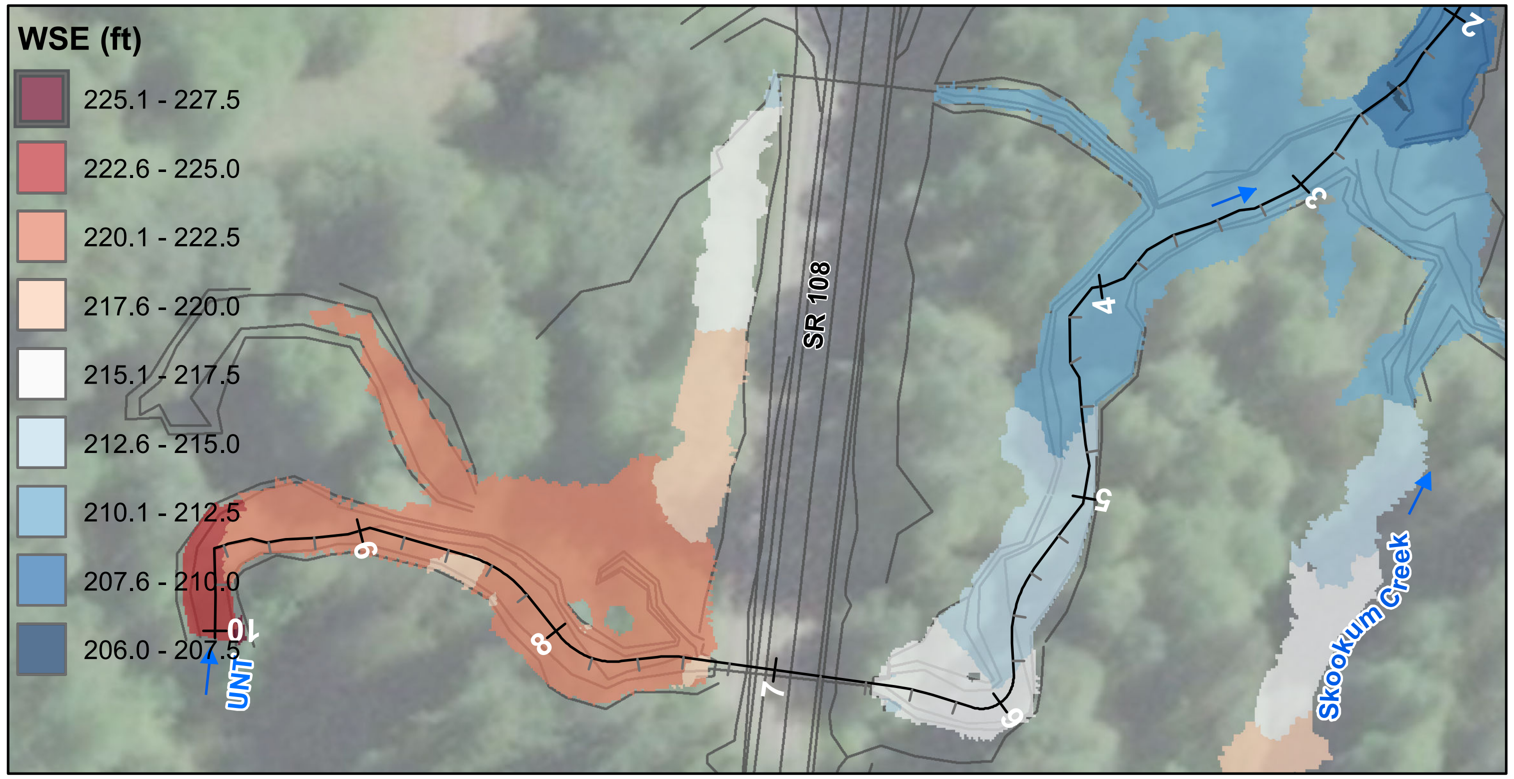

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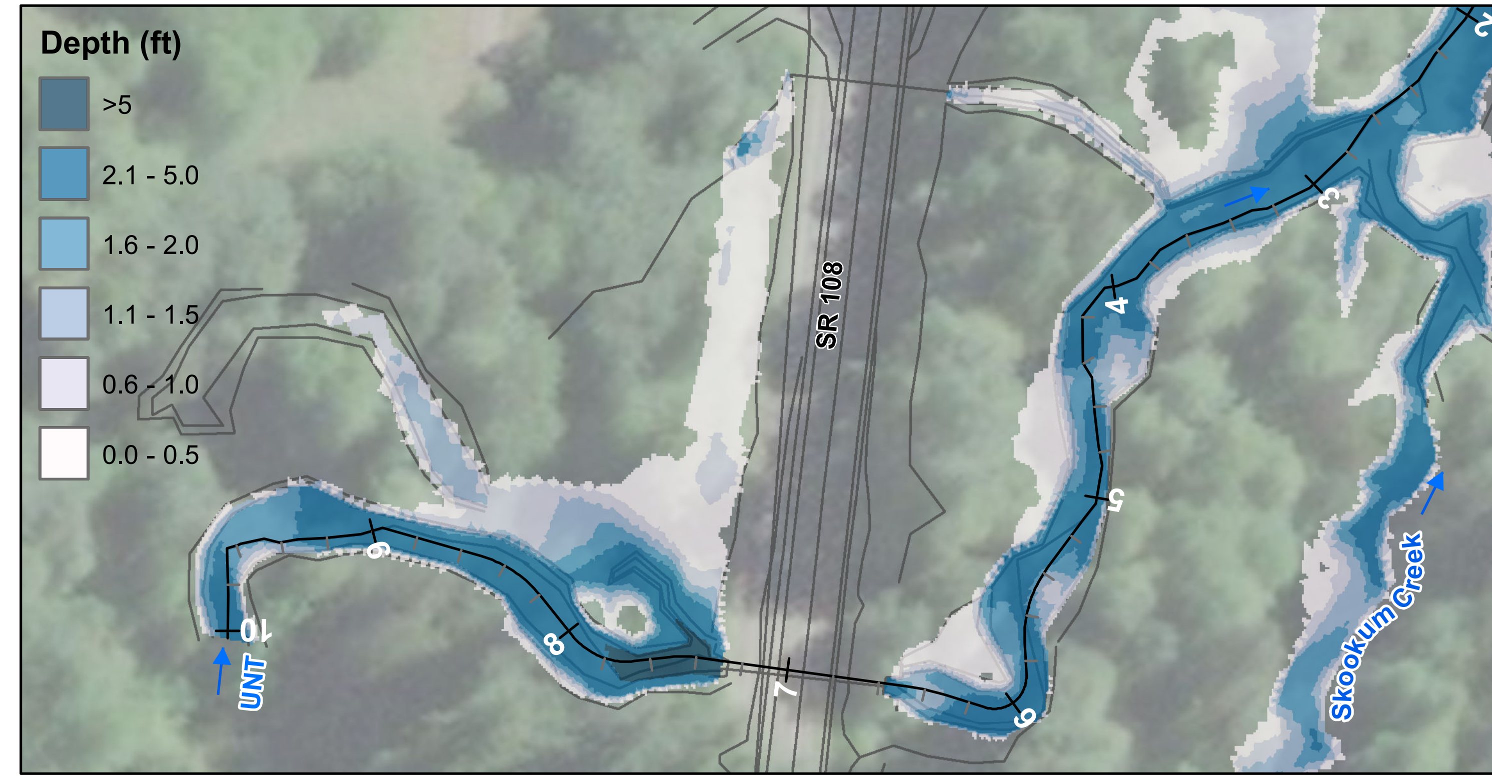

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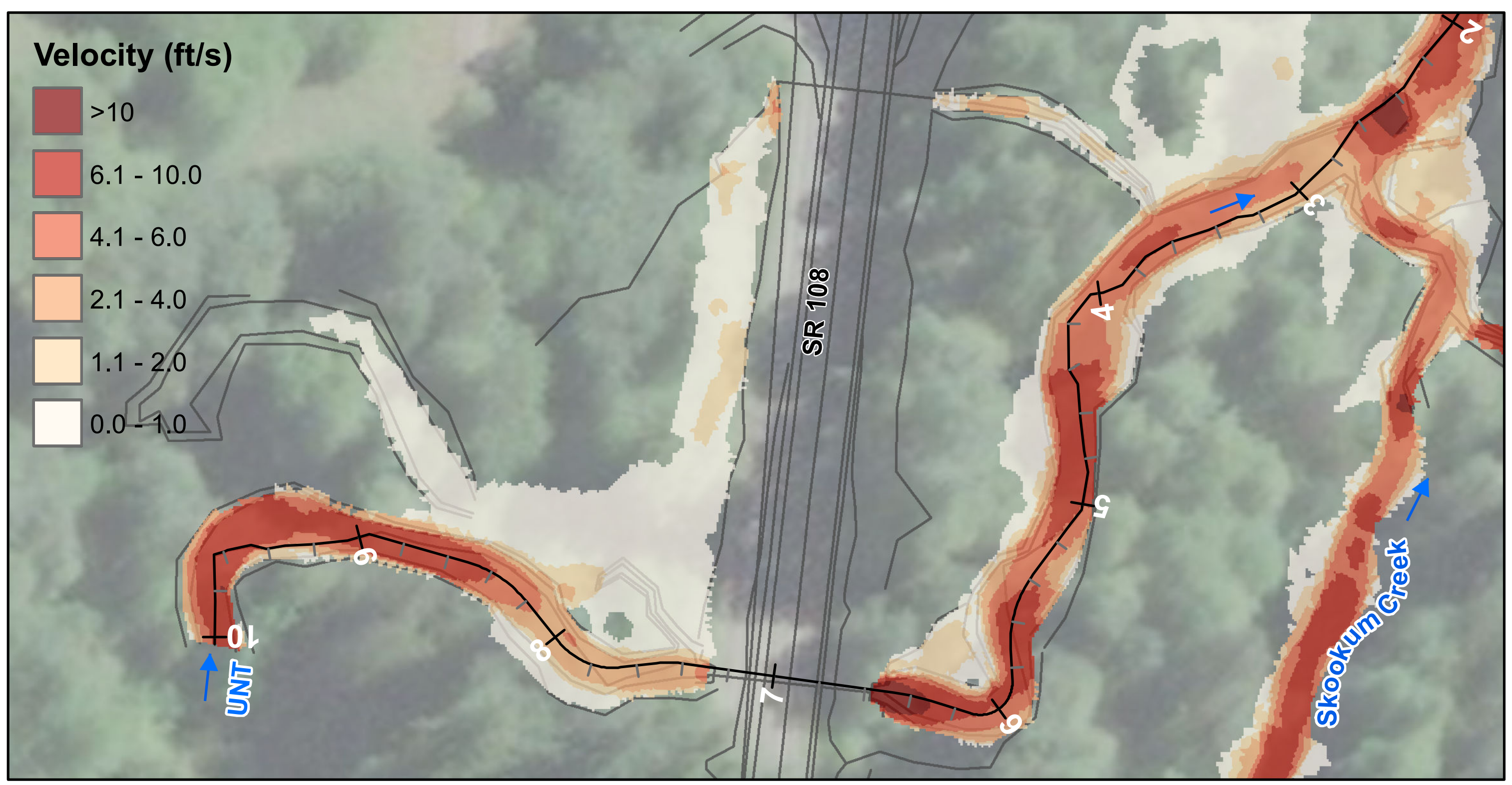

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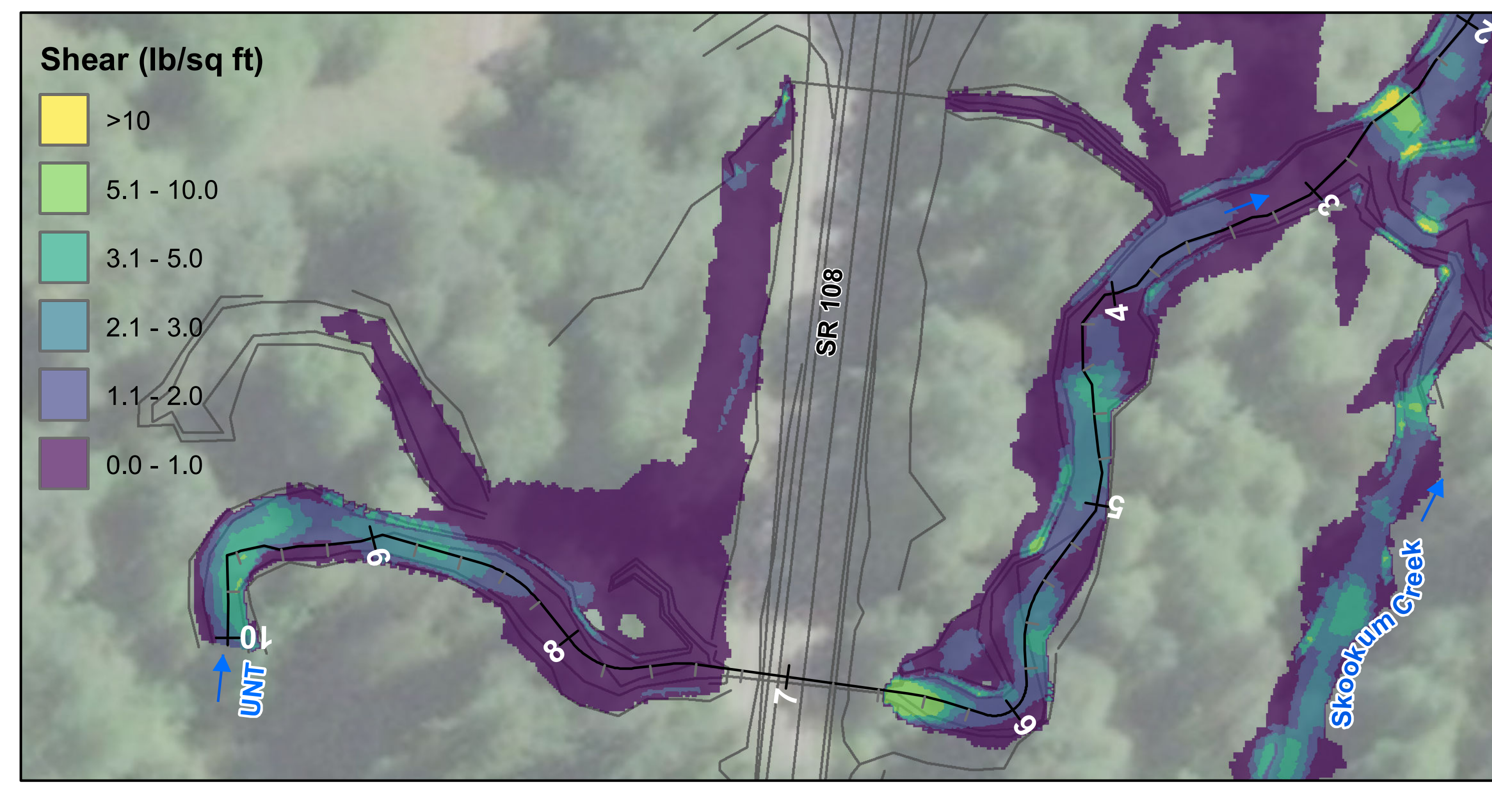

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HDR Washington State Department of Transportation

EXISTING CONDITIONS 50-YEAR

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MP 5.54

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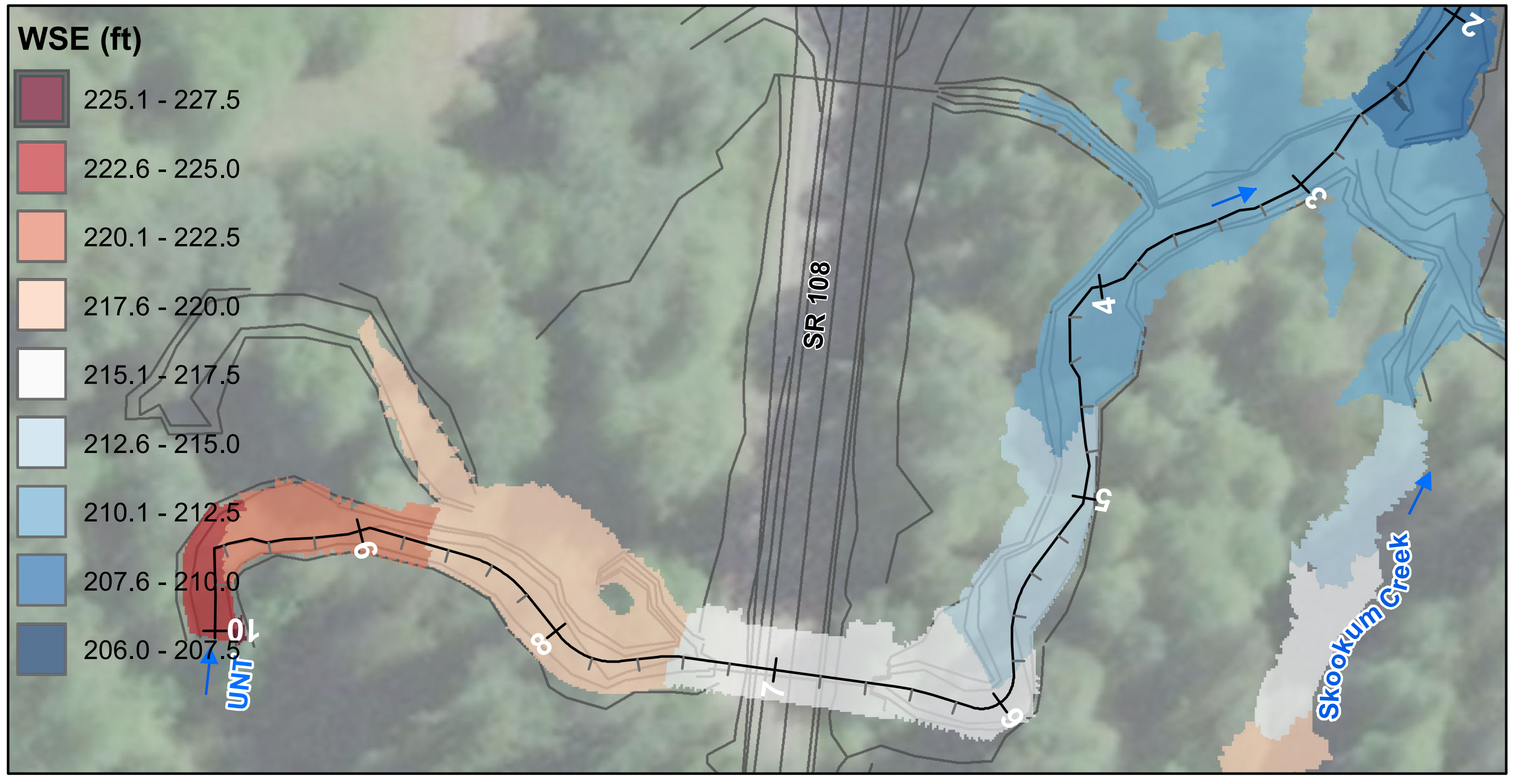

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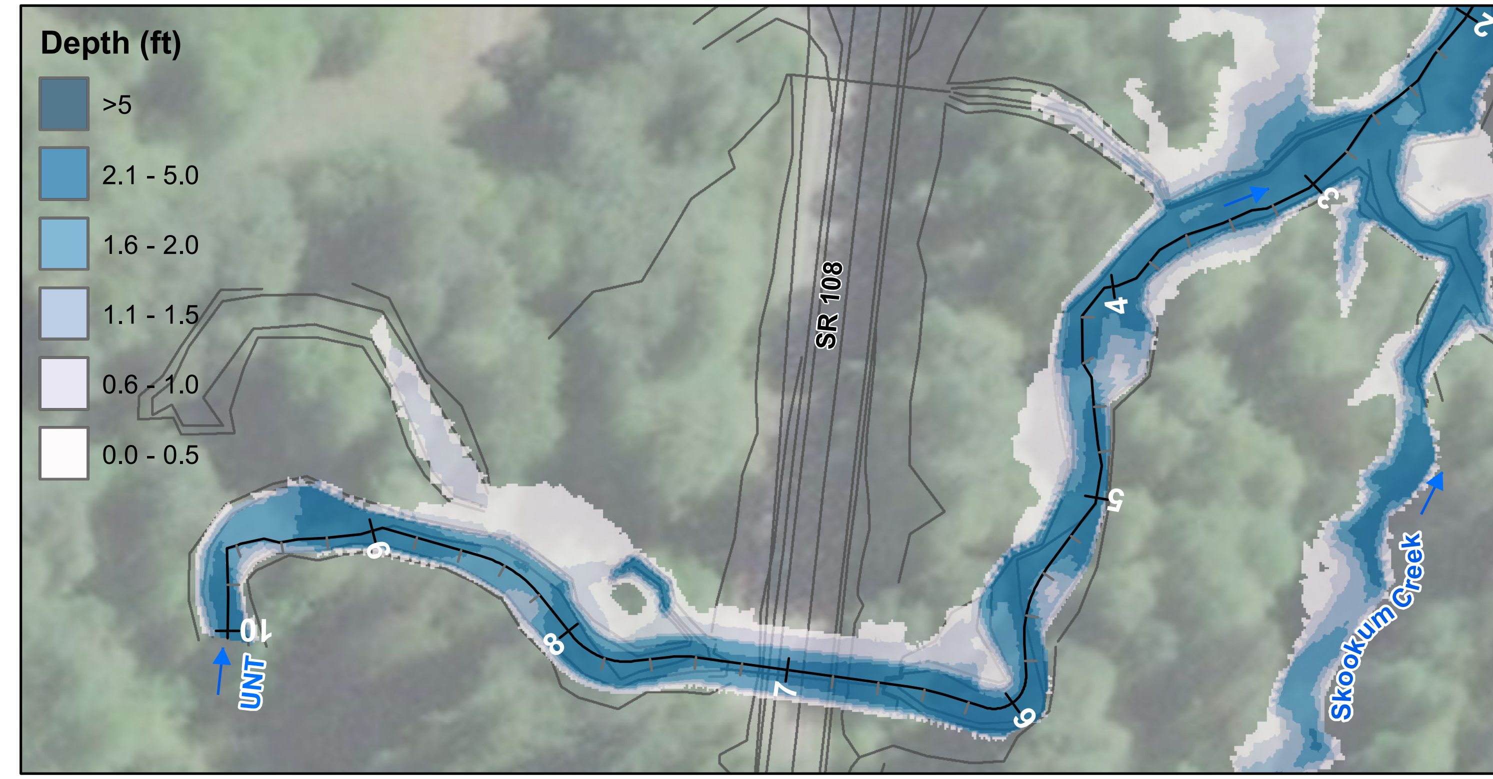

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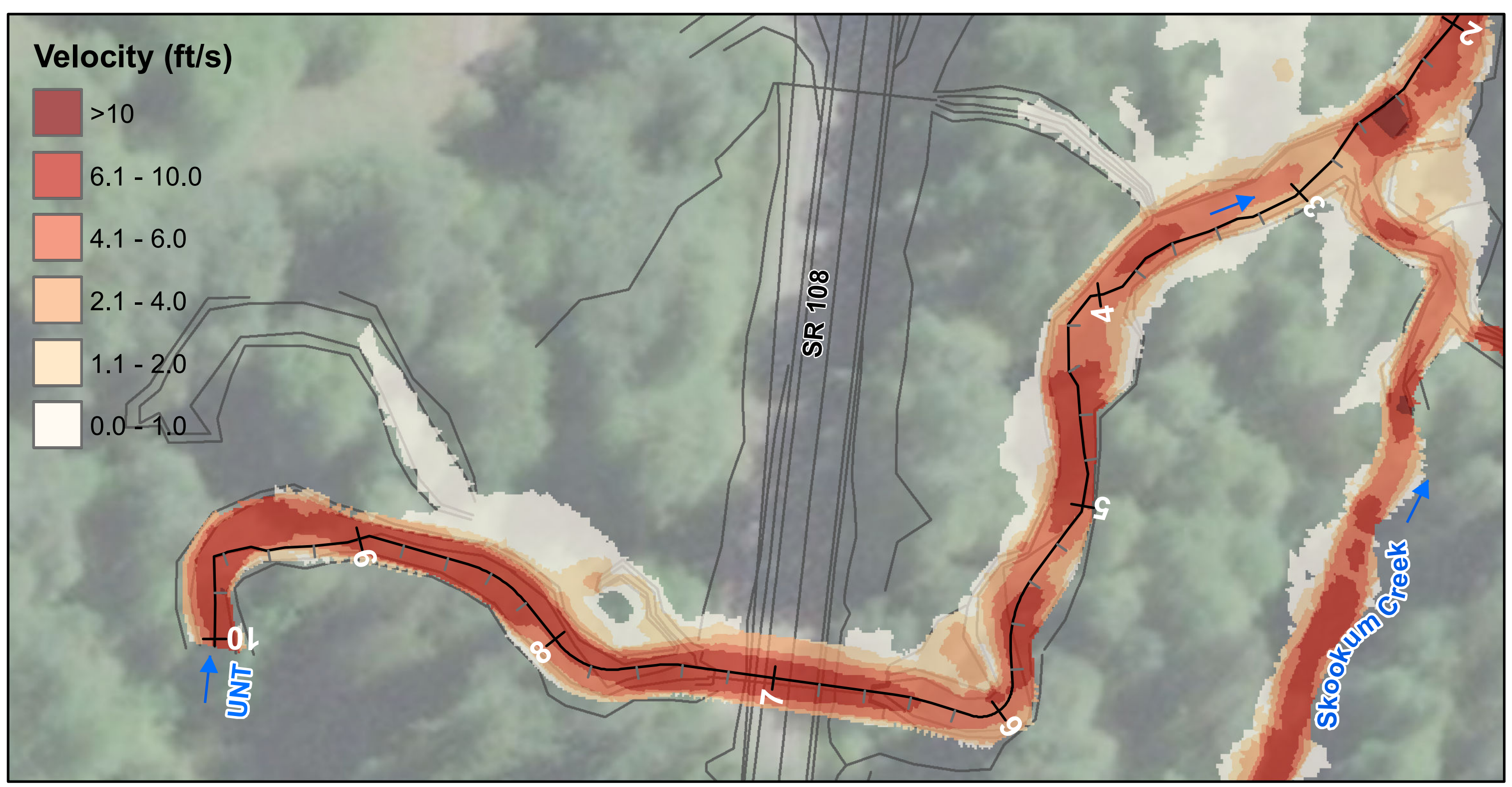

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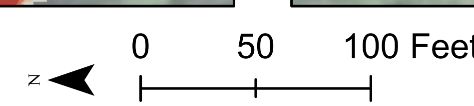

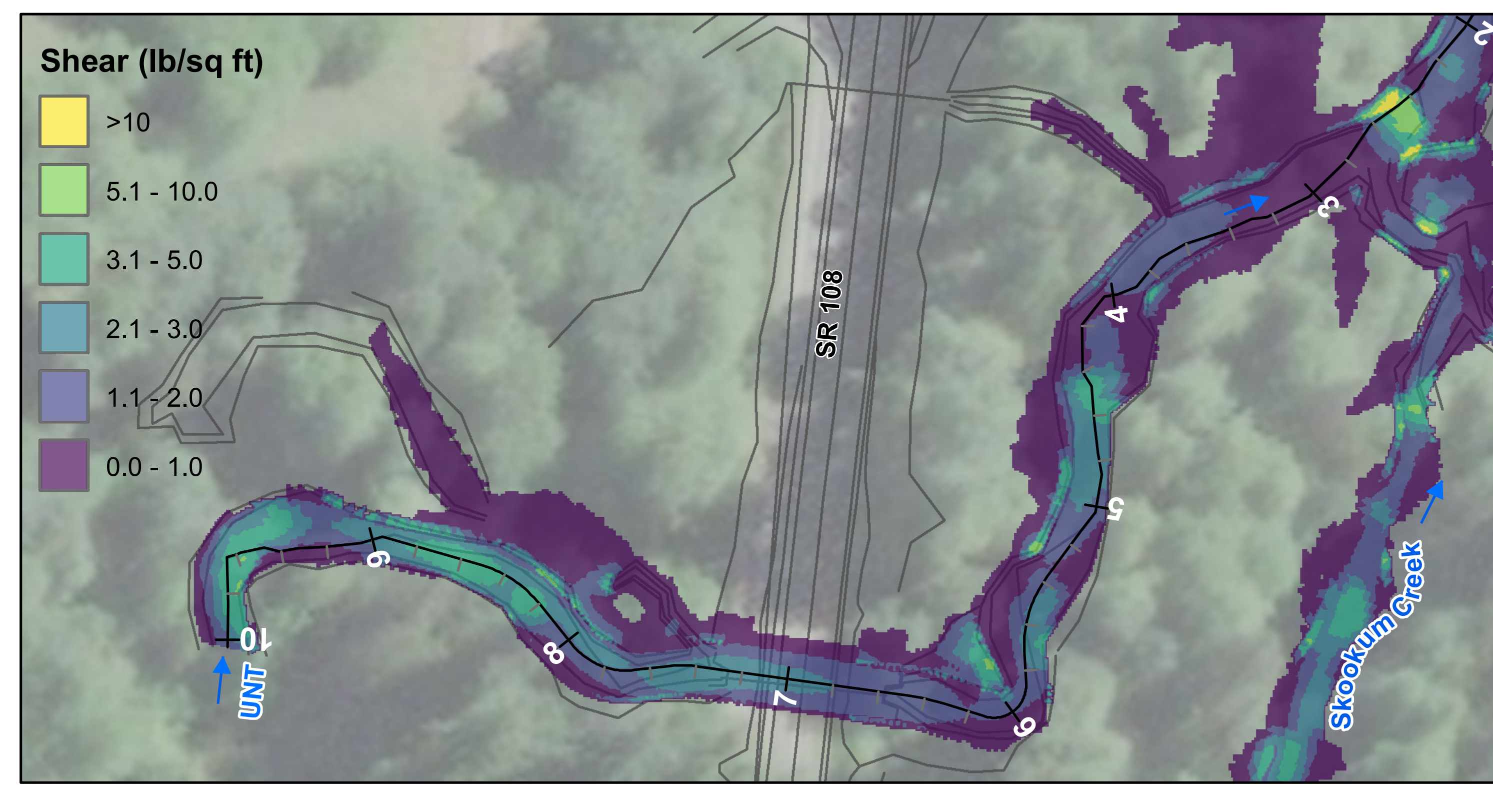

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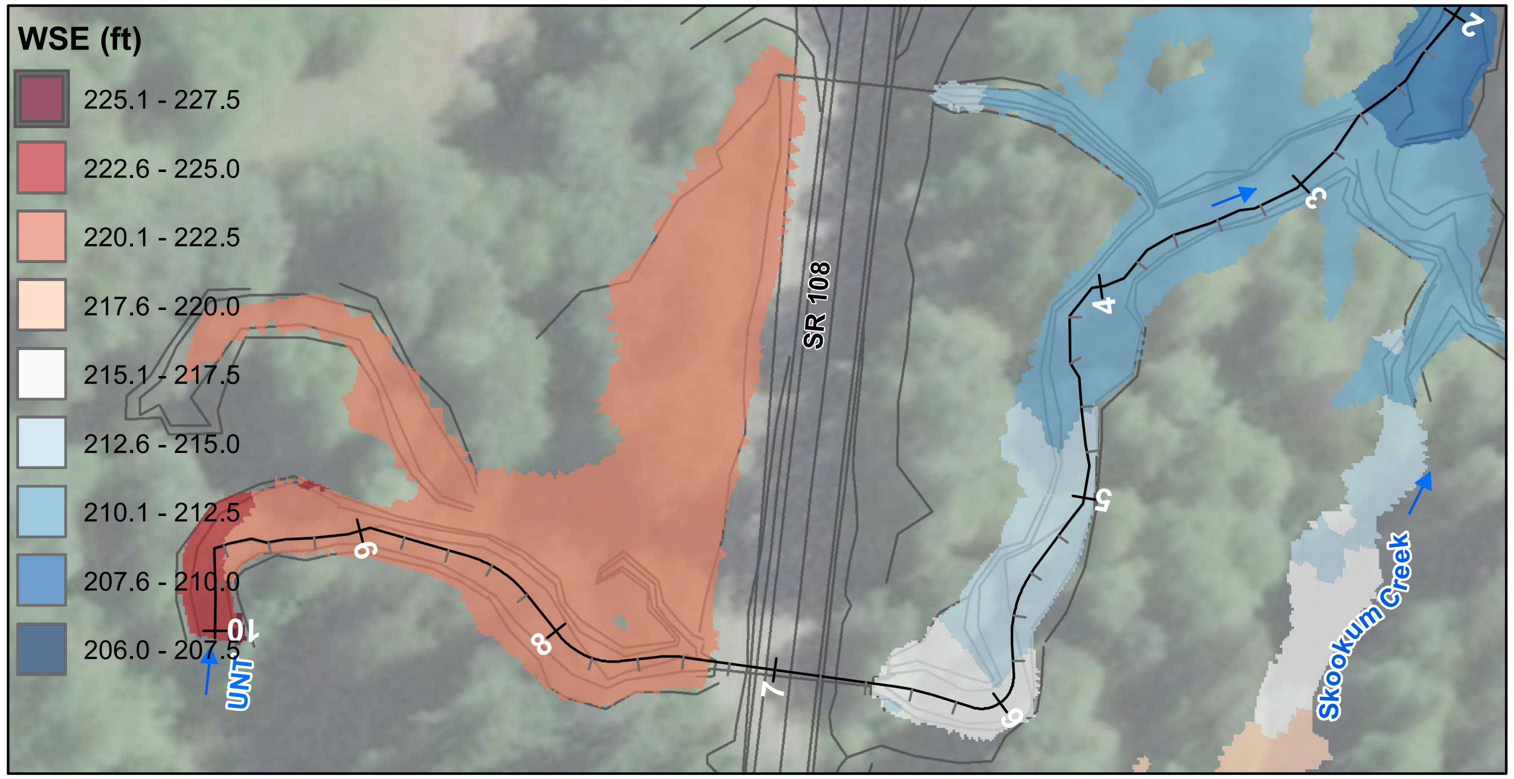
Washington State Department of Transportation

PROPOSED CONDITIONS 50-YEAR

SR 108 UNNAMED TRIBUTARY TO SKOOKUM CREEK
MP 5.54



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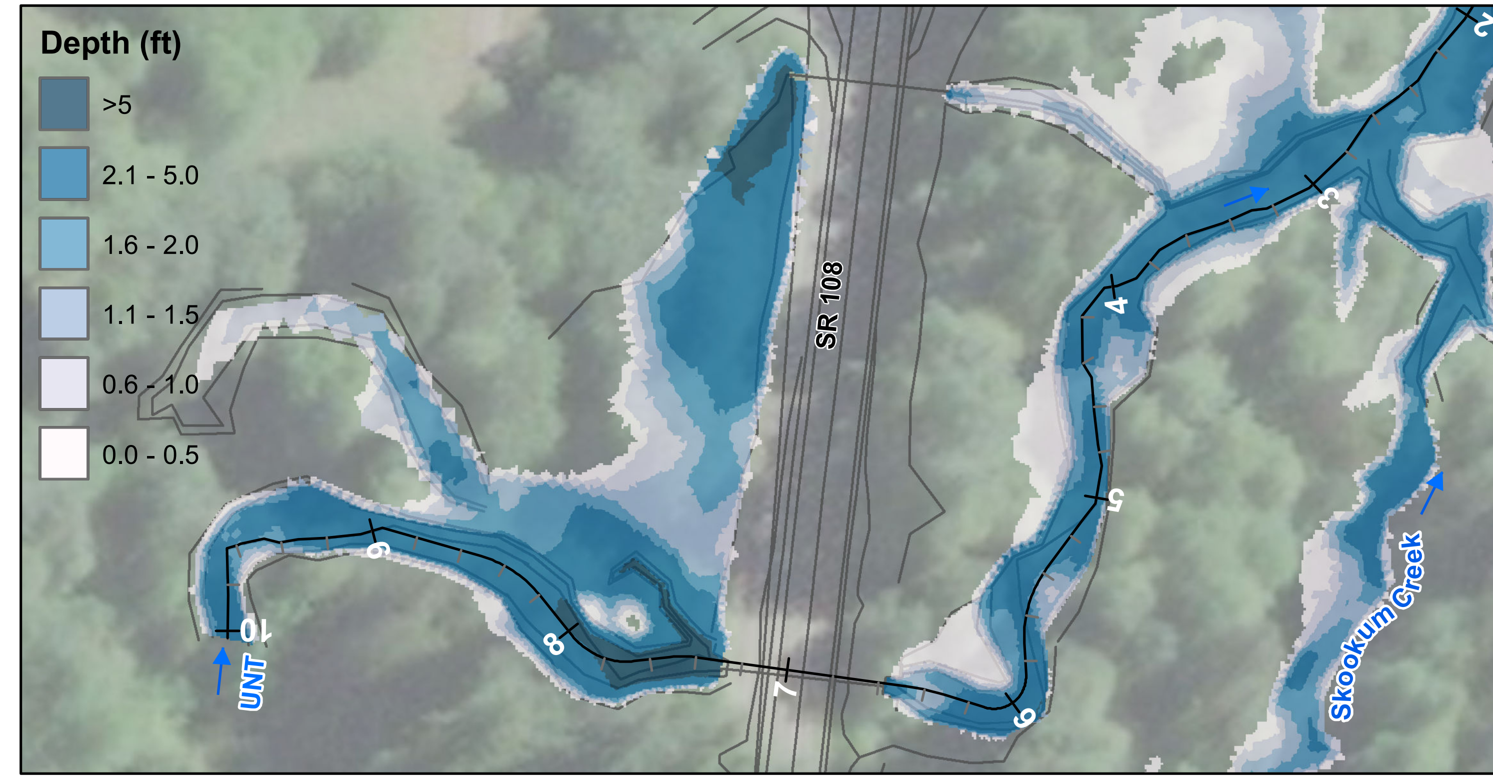

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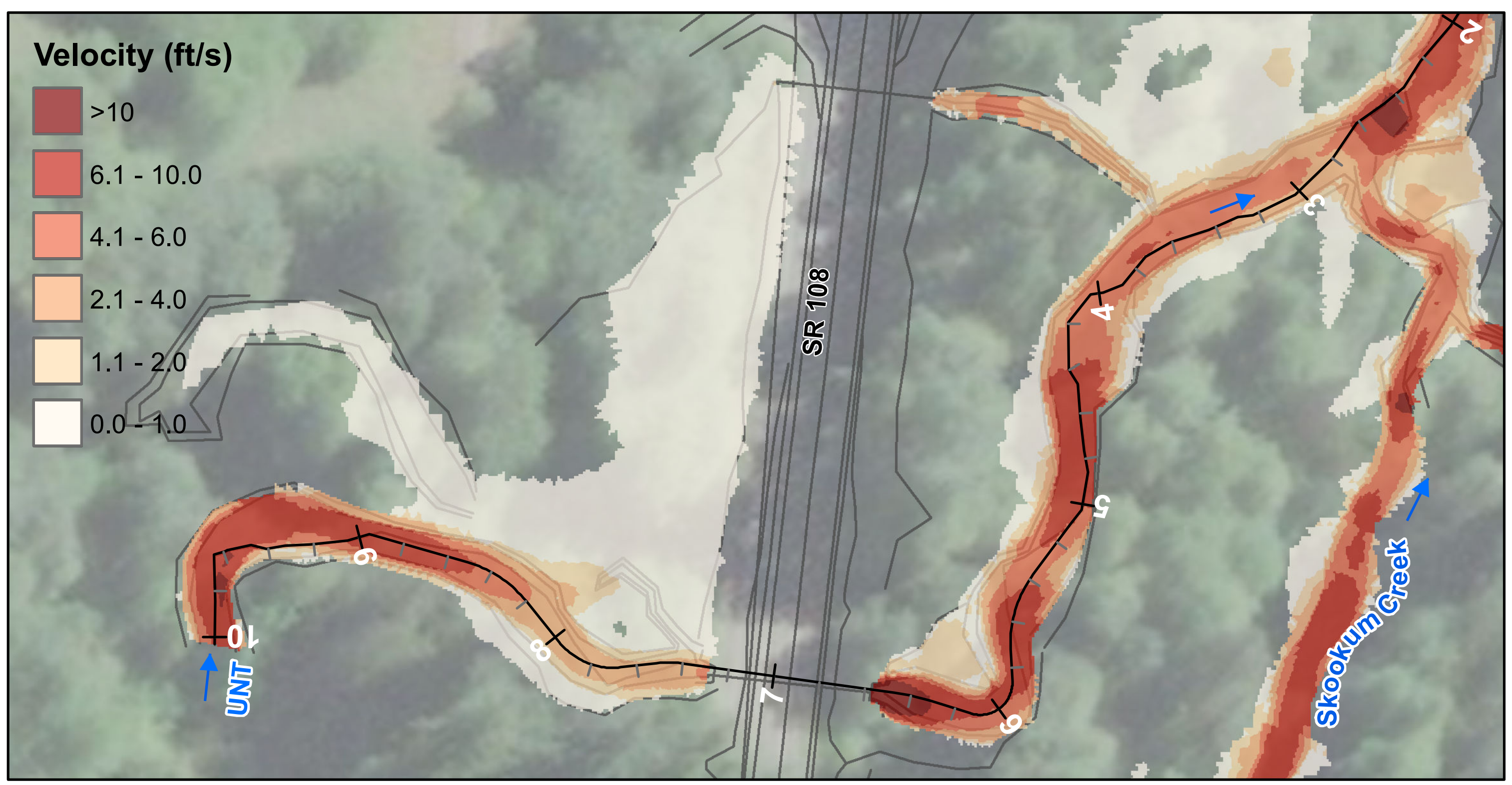

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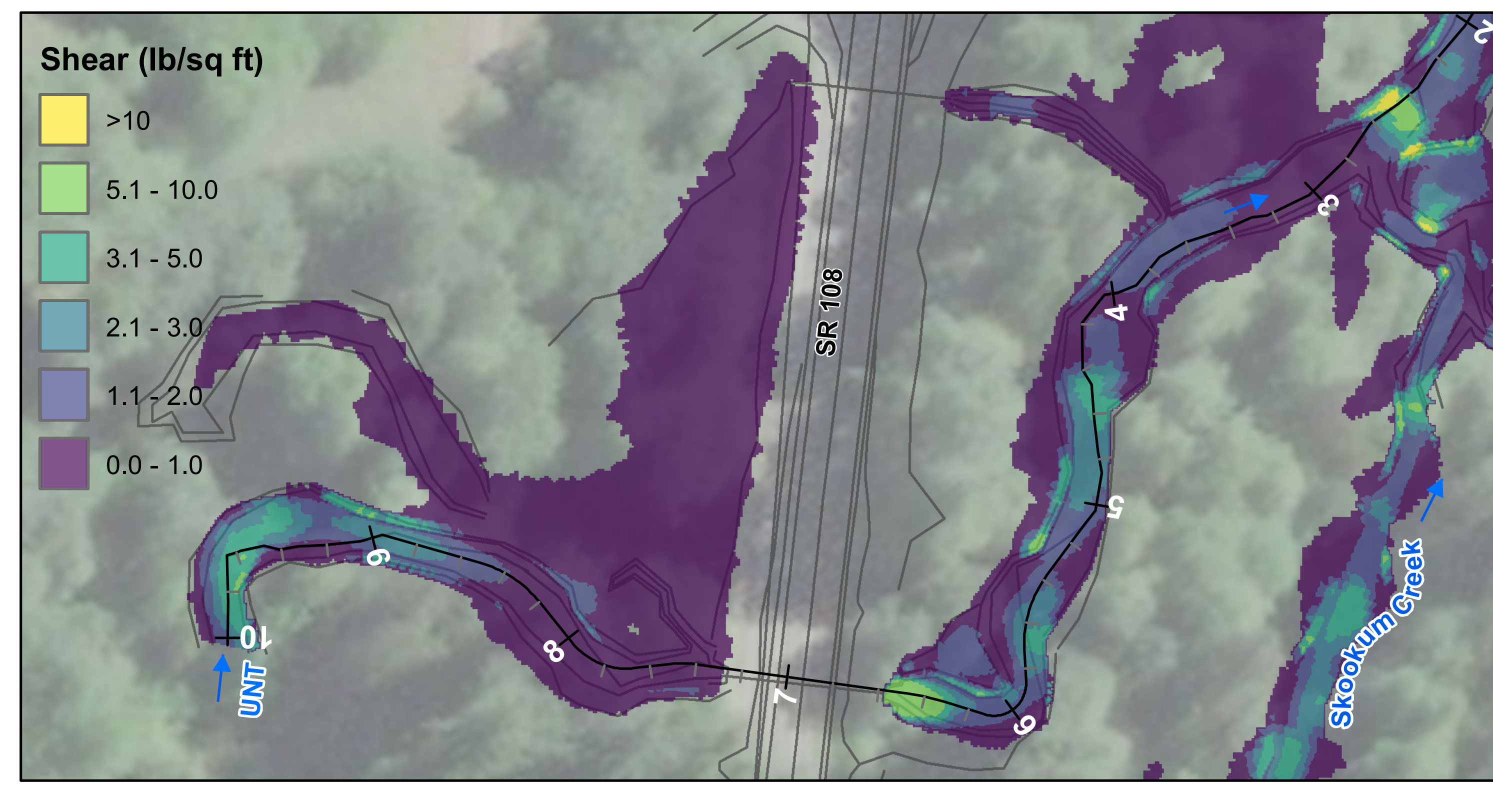


SHEAR

N

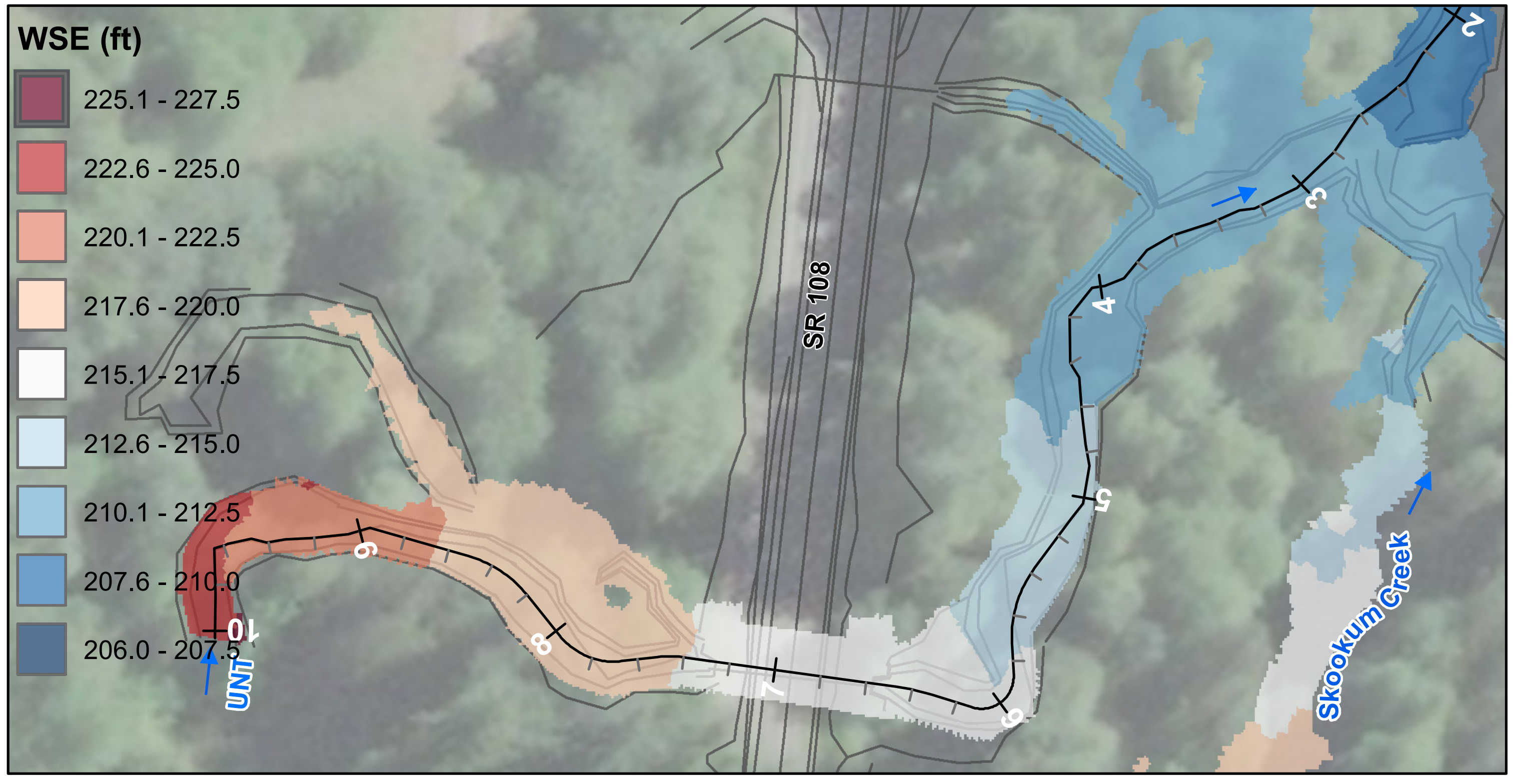
0 50 100 Feet

HDR

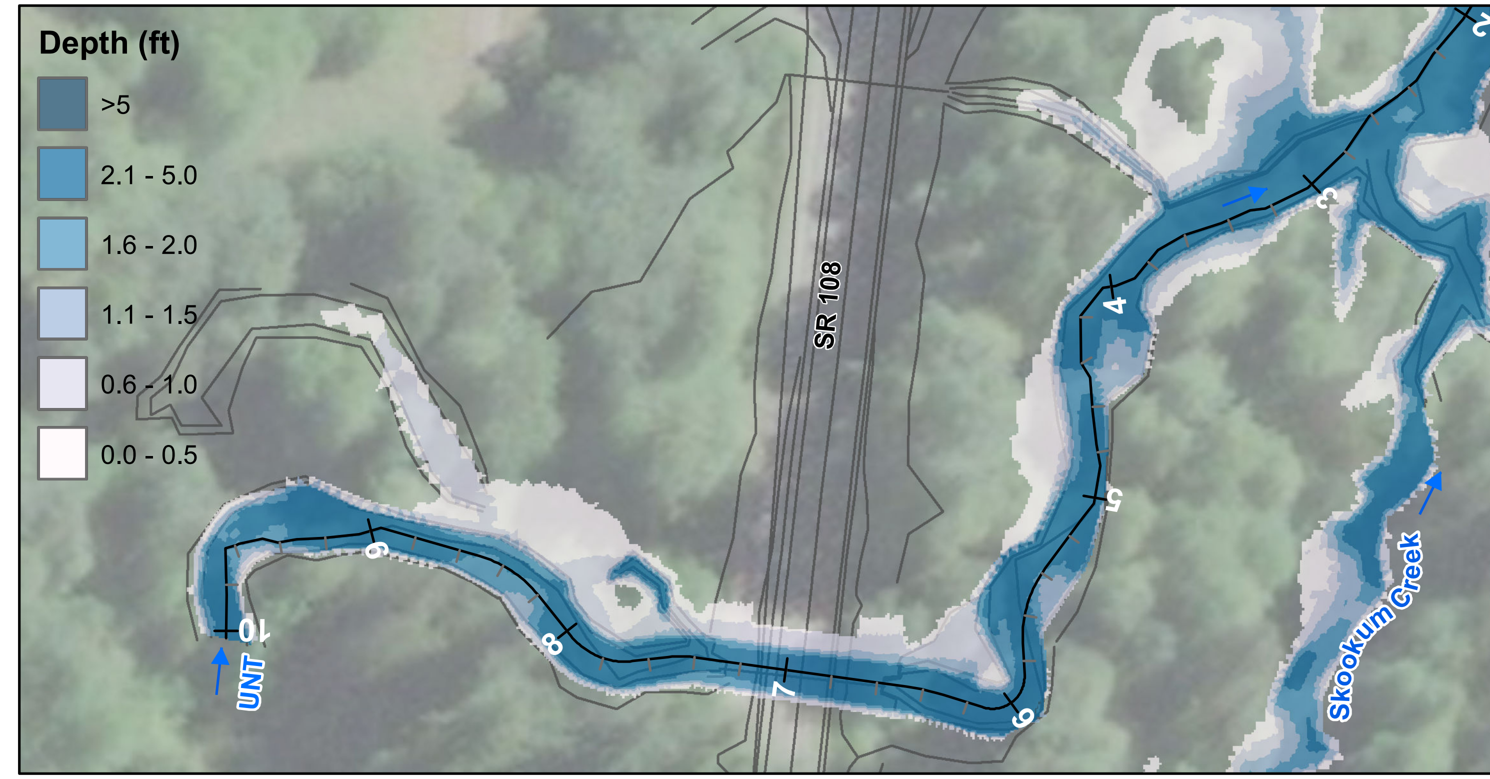
Washington State Department of Transportation

EXISTING CONDITIONS 100-YEAR

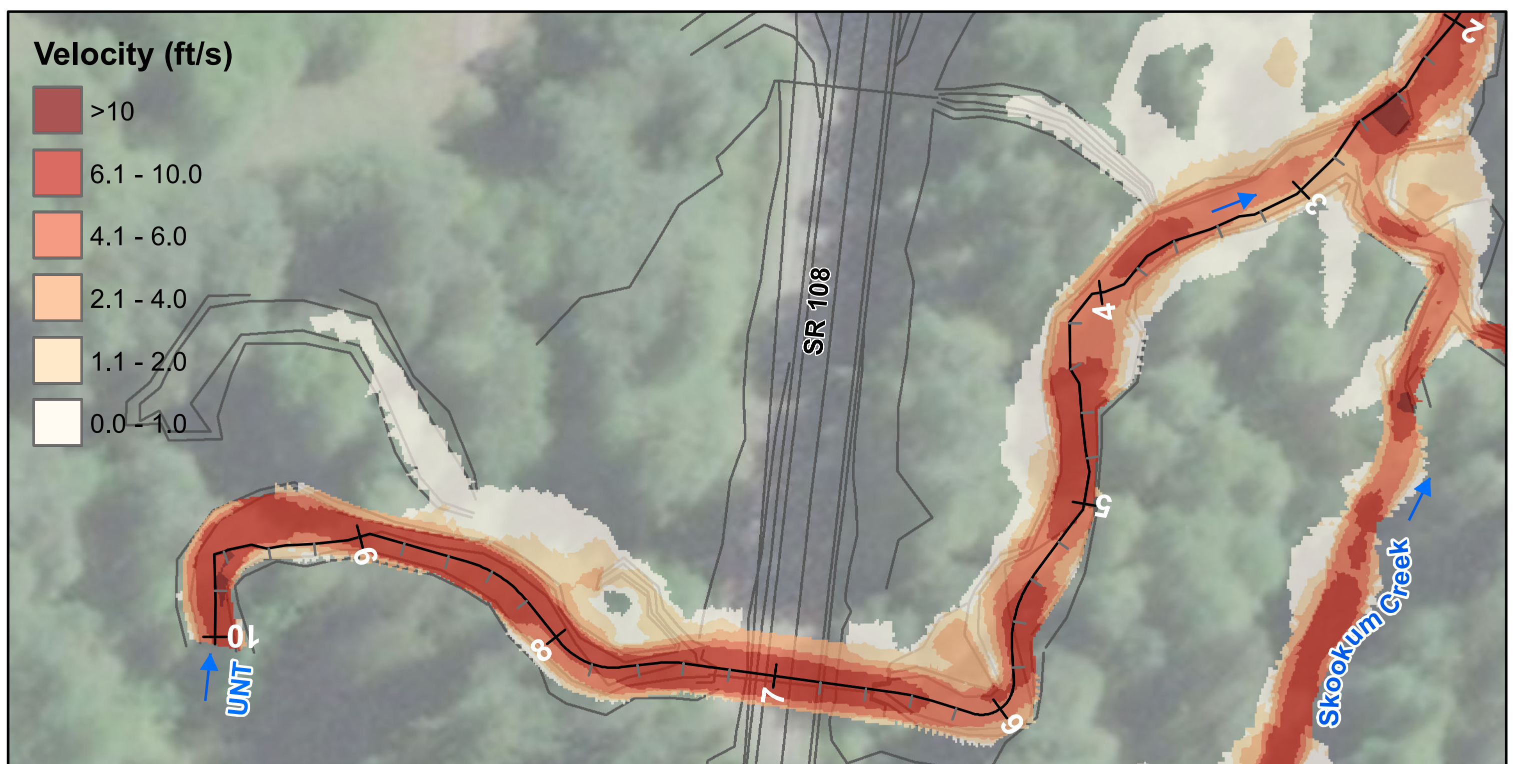
SR 108 UNNAMED TRIBUTARY TO SKOOKUM CREEK
MP 5.54



WATER SURFACE ELEVATION



DEPTH



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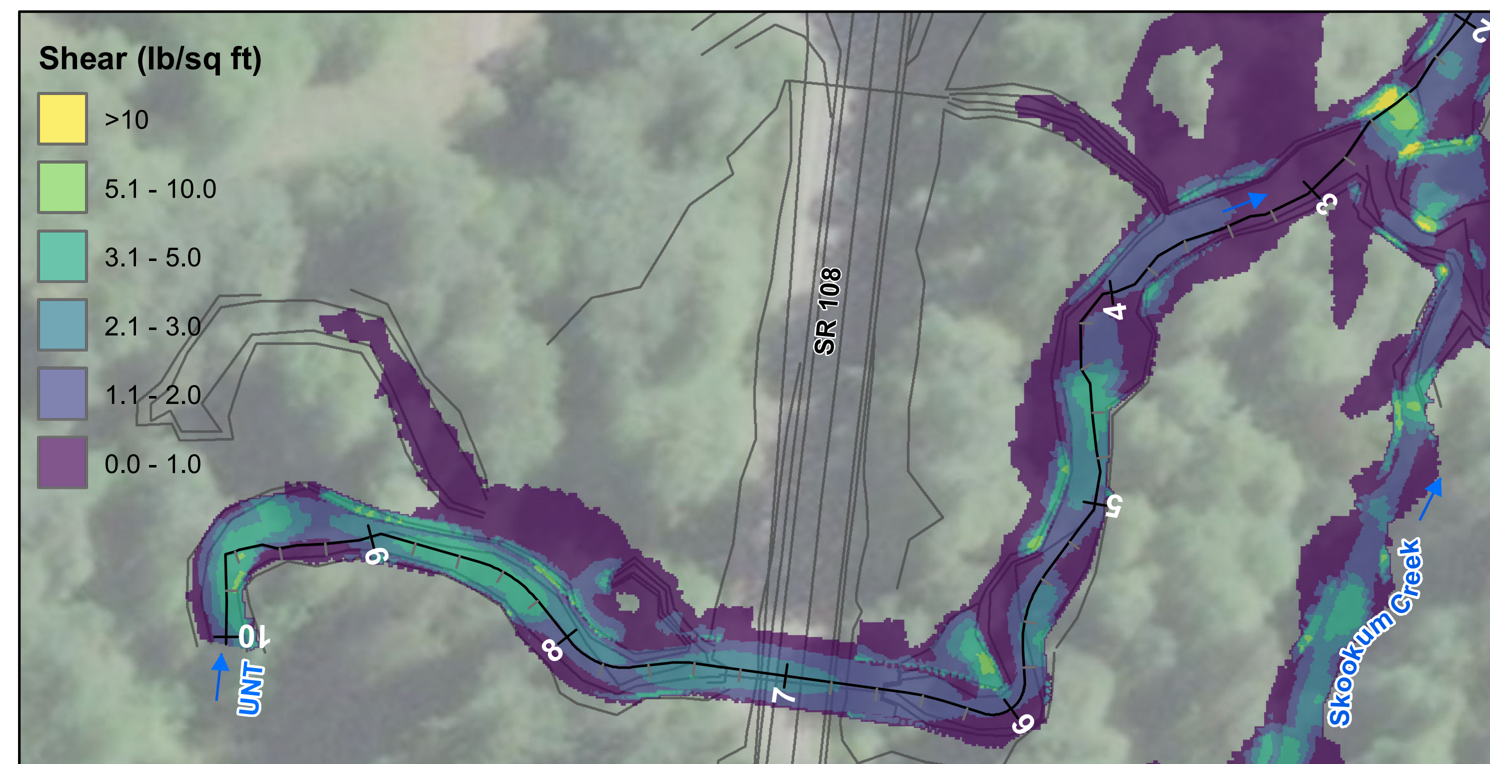

SHEAR

N

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HDR

Washington State Department of Transportation

PROPOSED CONDITIONS 100-YEAR

SR 108 UNNAMED TRIBUTARY TO SKOOKUM CREEK
MP 5.54

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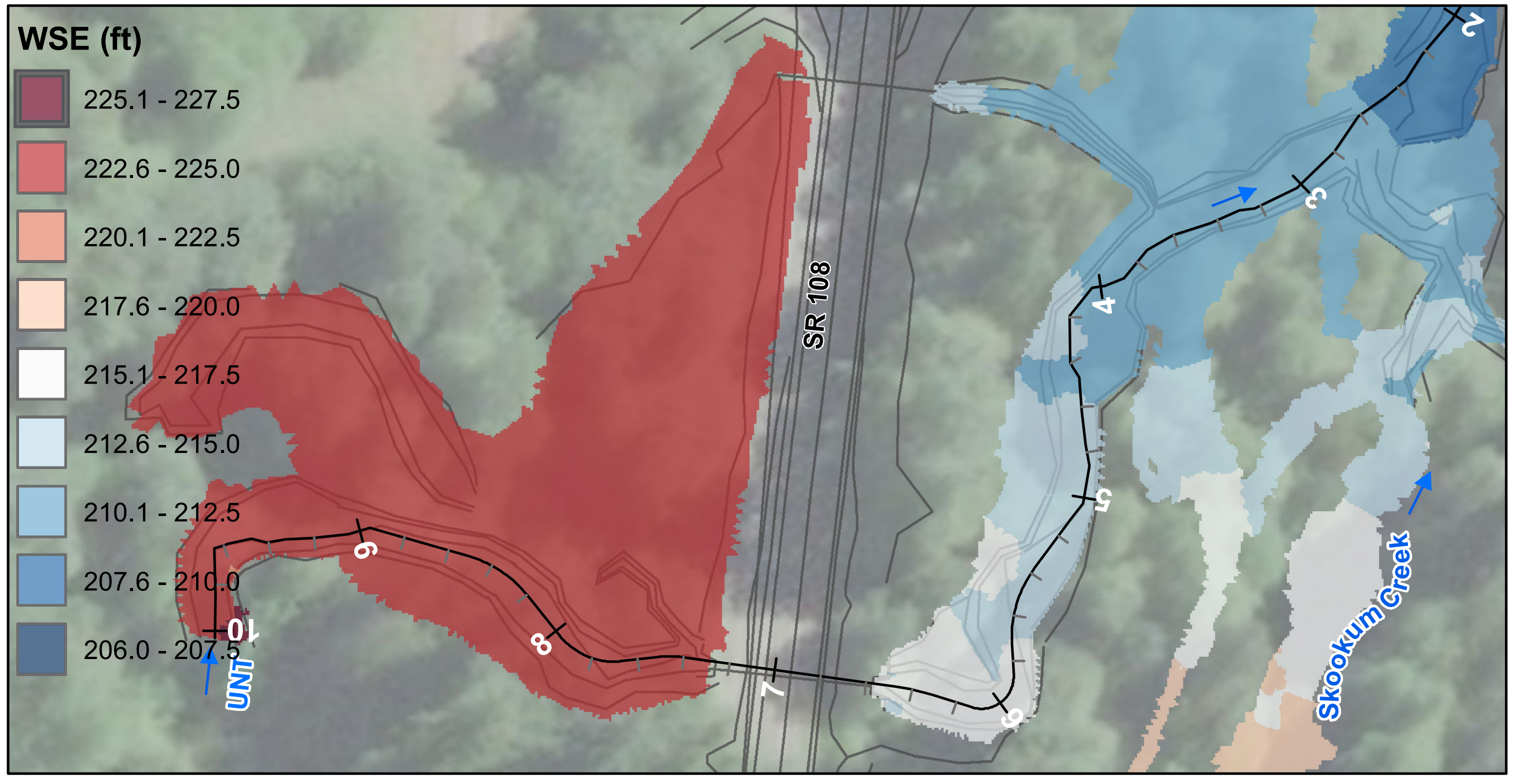

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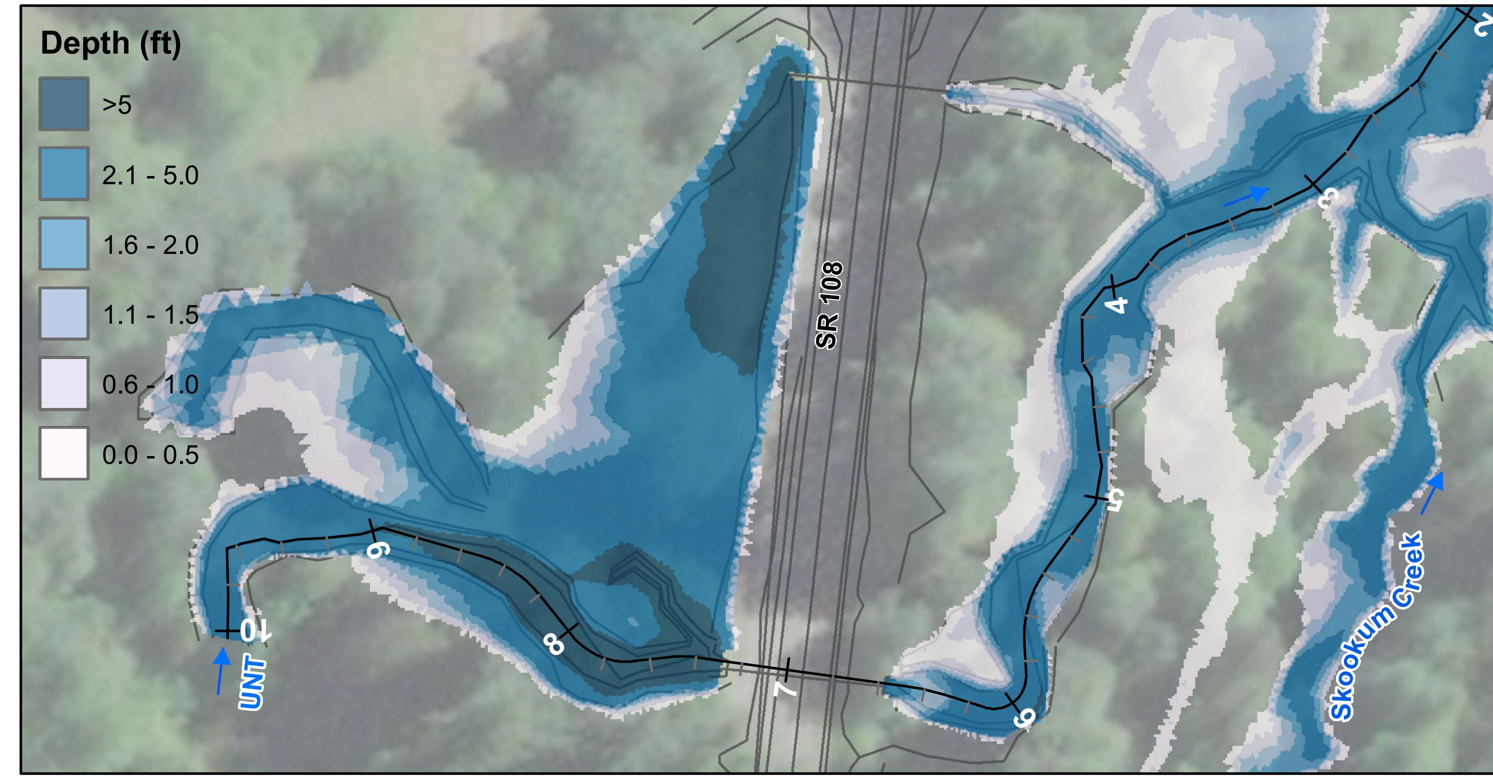

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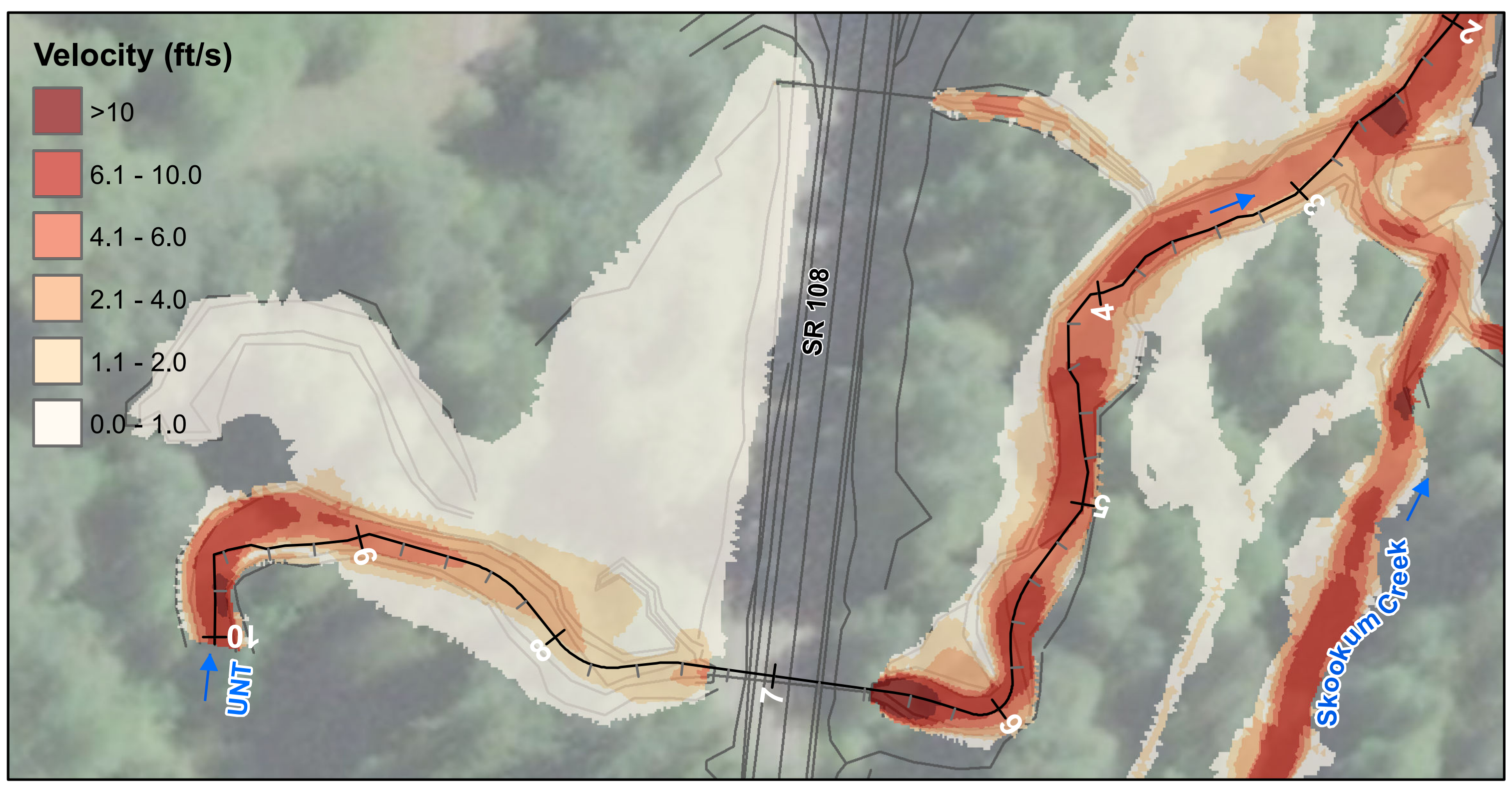

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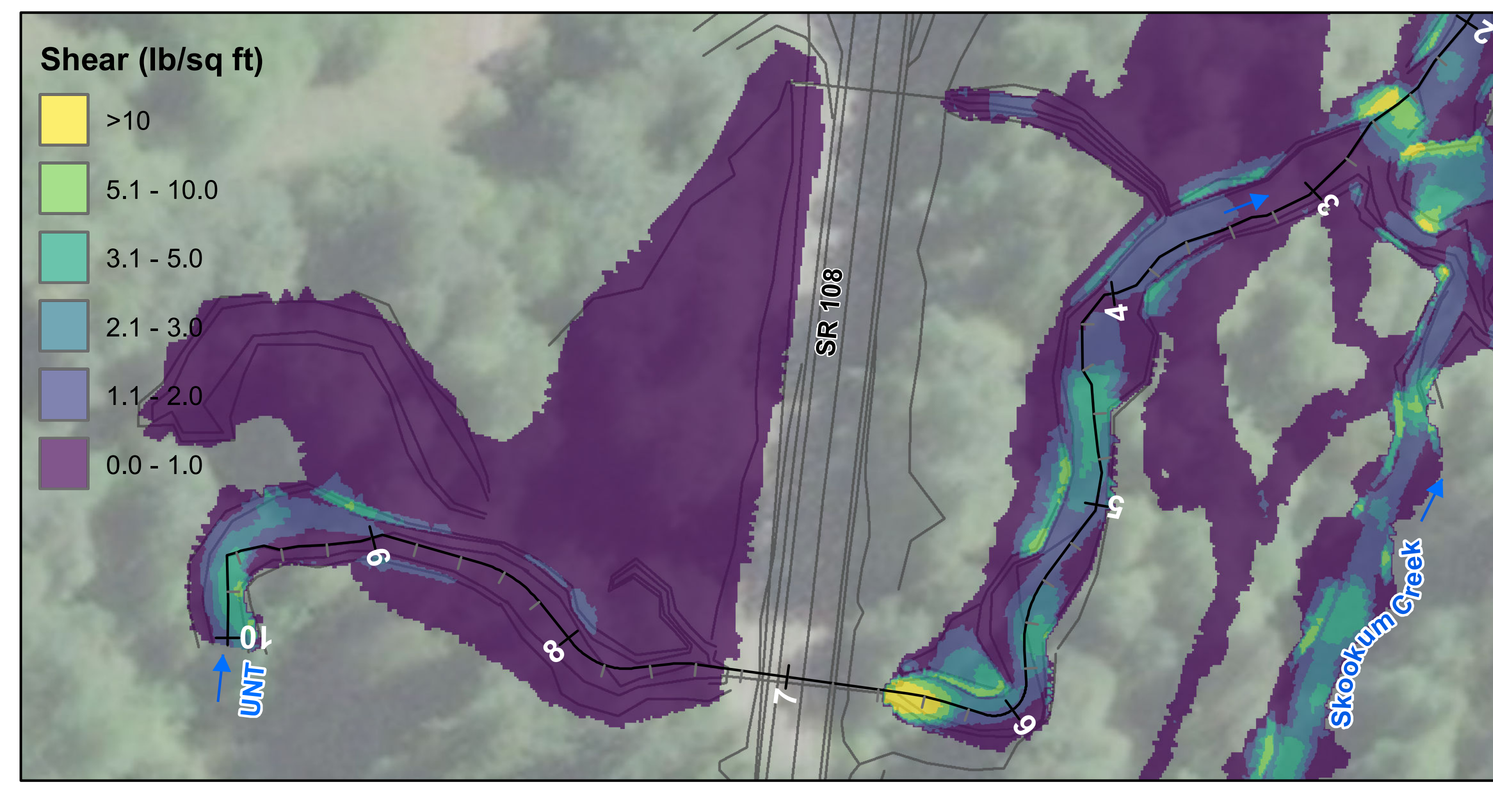


SHEAR

N

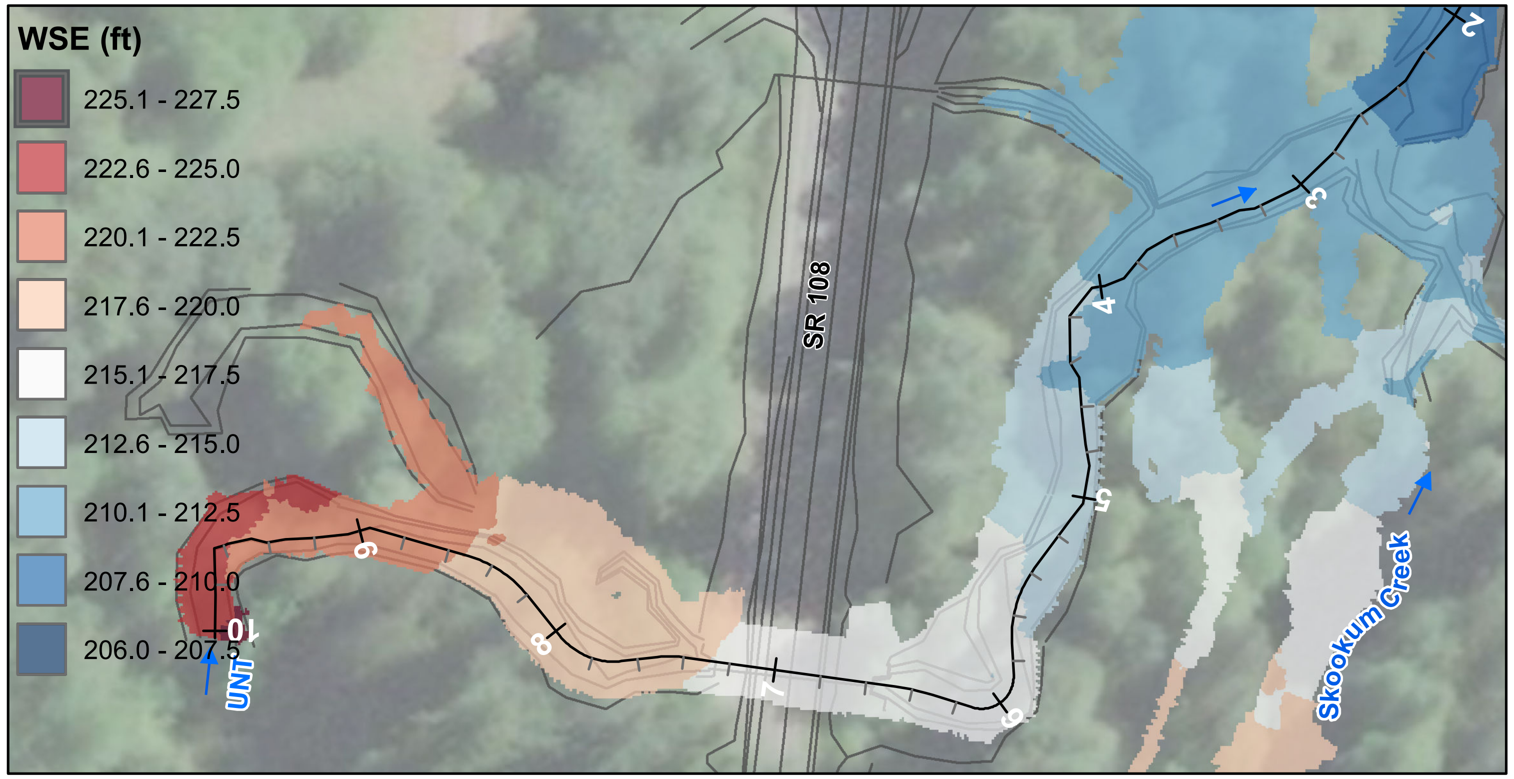
0 50 100 Feet

HDR

Washington State Department of Transportation

EXISTING CONDITIONS 500-YEAR

SR 108 UNNAMED TRIBUTARY TO SKOOKUM CREEK
MP 5.54



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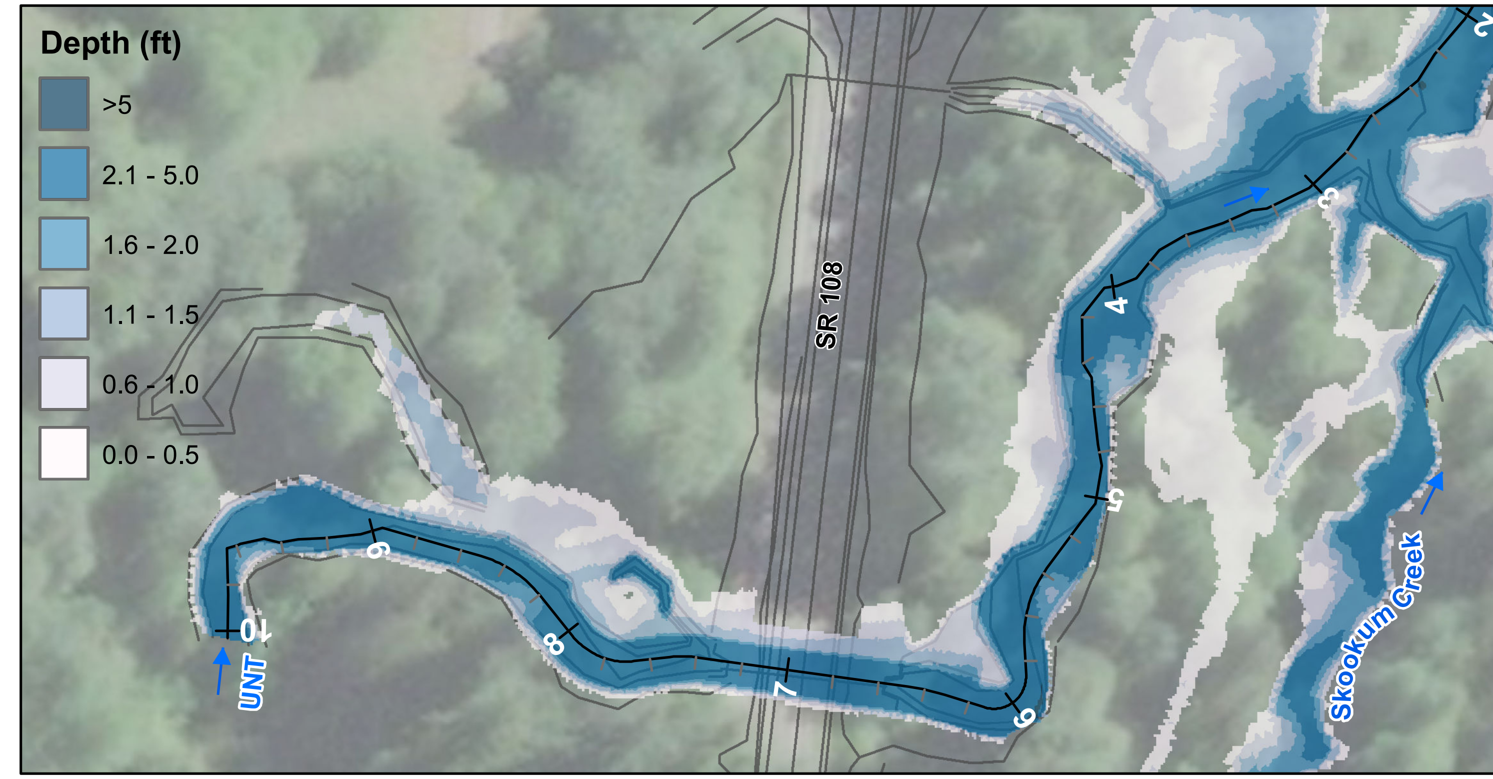

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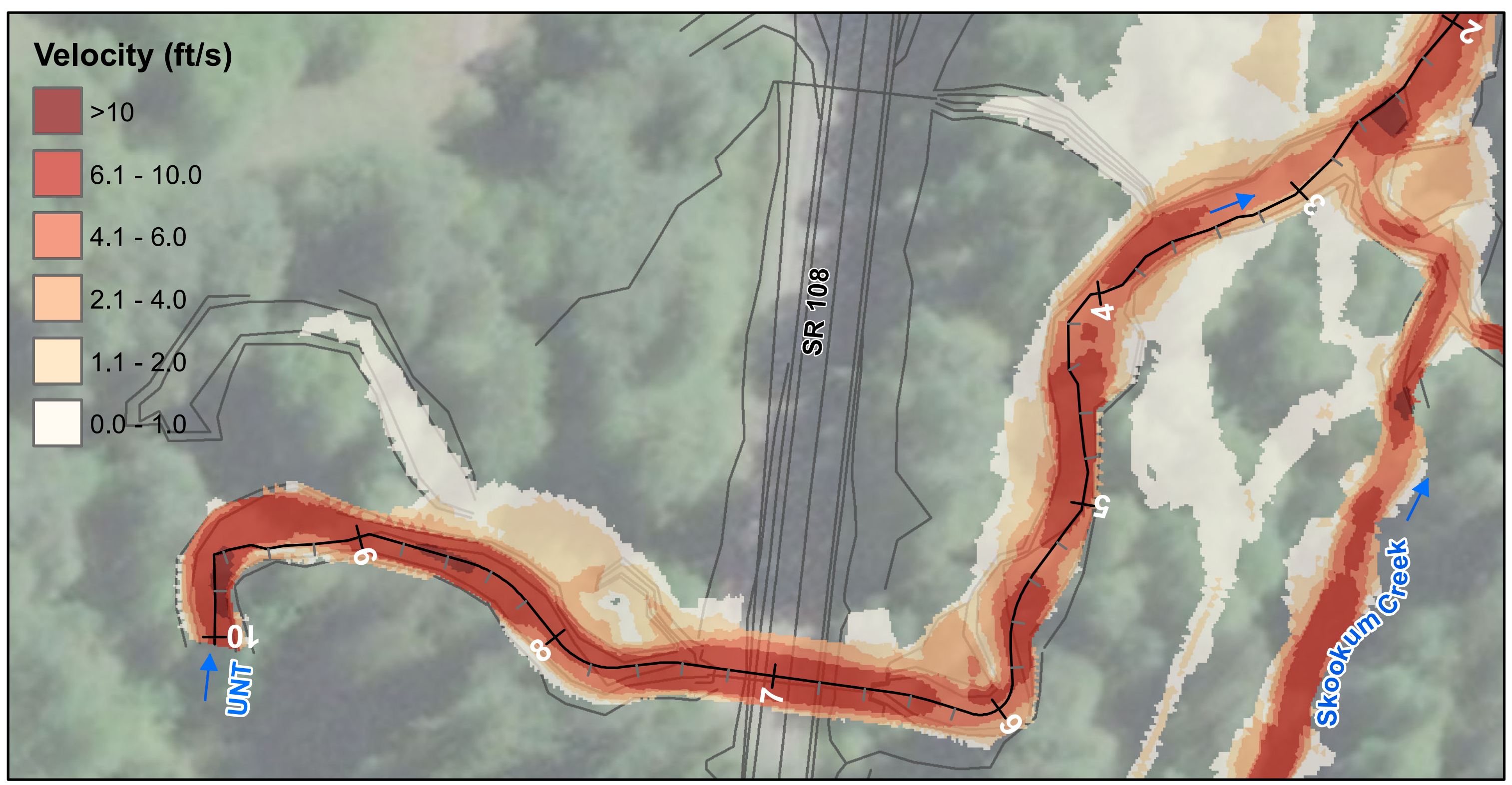

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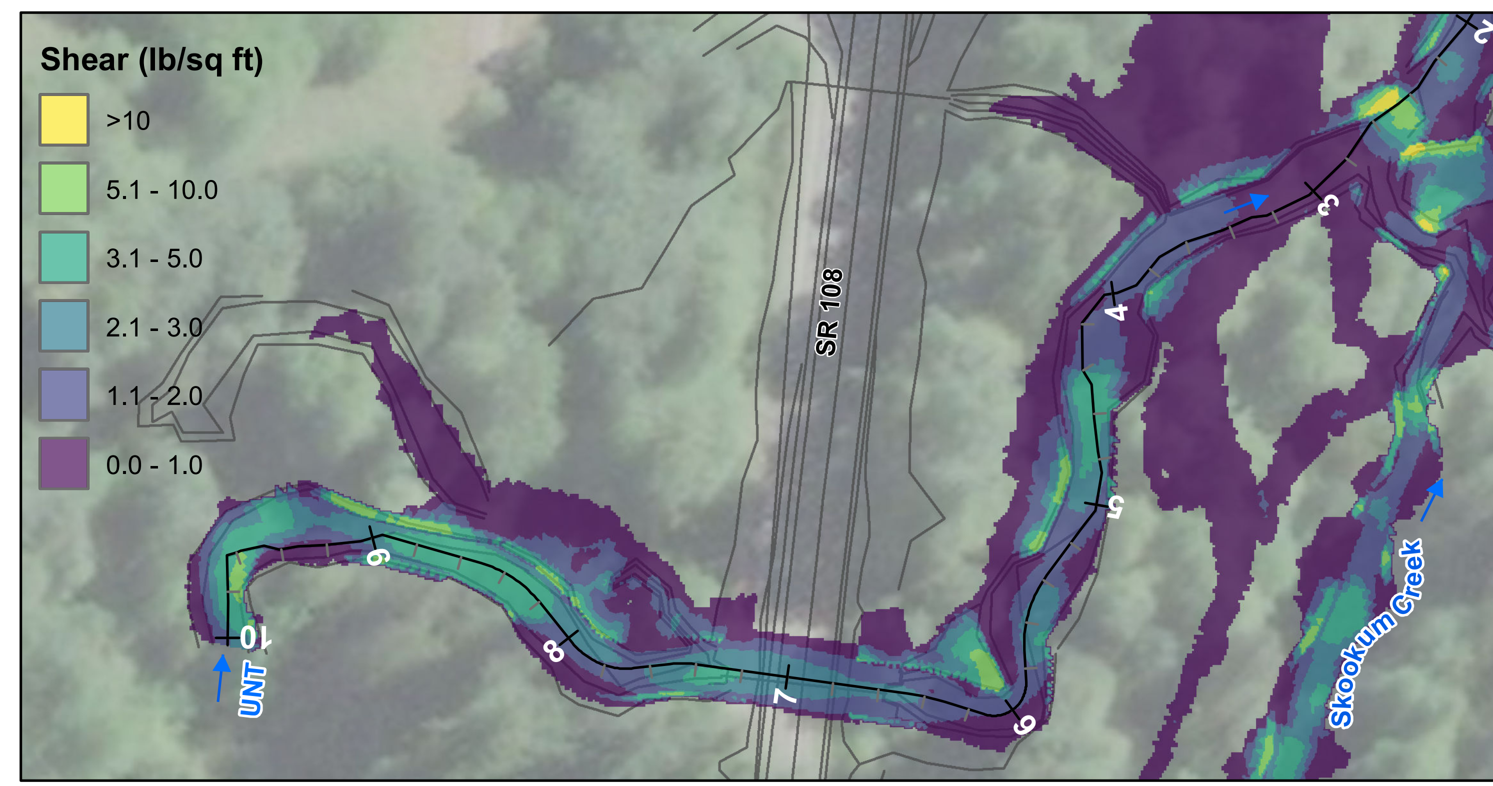


SHEAR

N

0 50 100 Feet

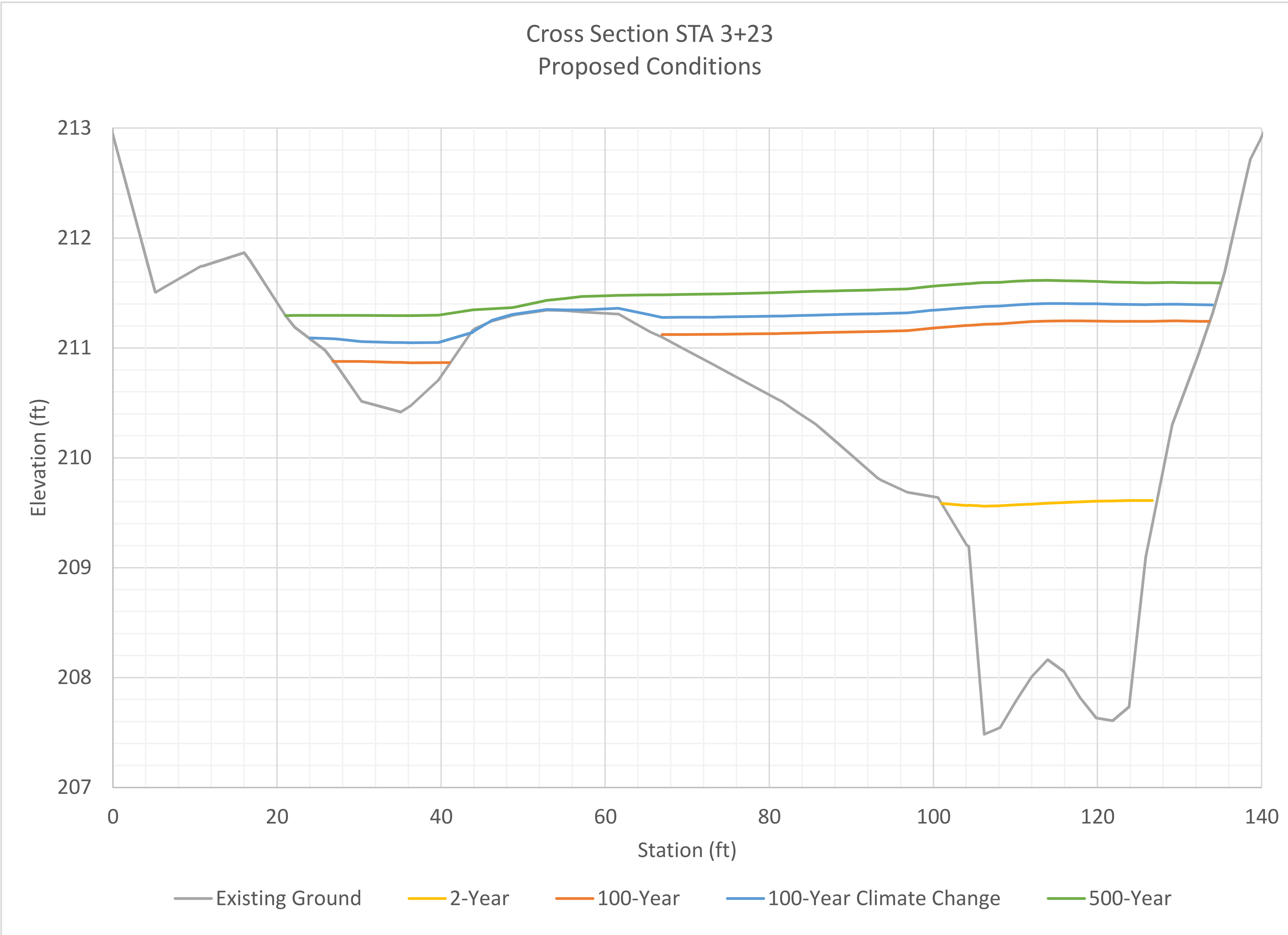
HDR

Washington State Department of Transportation

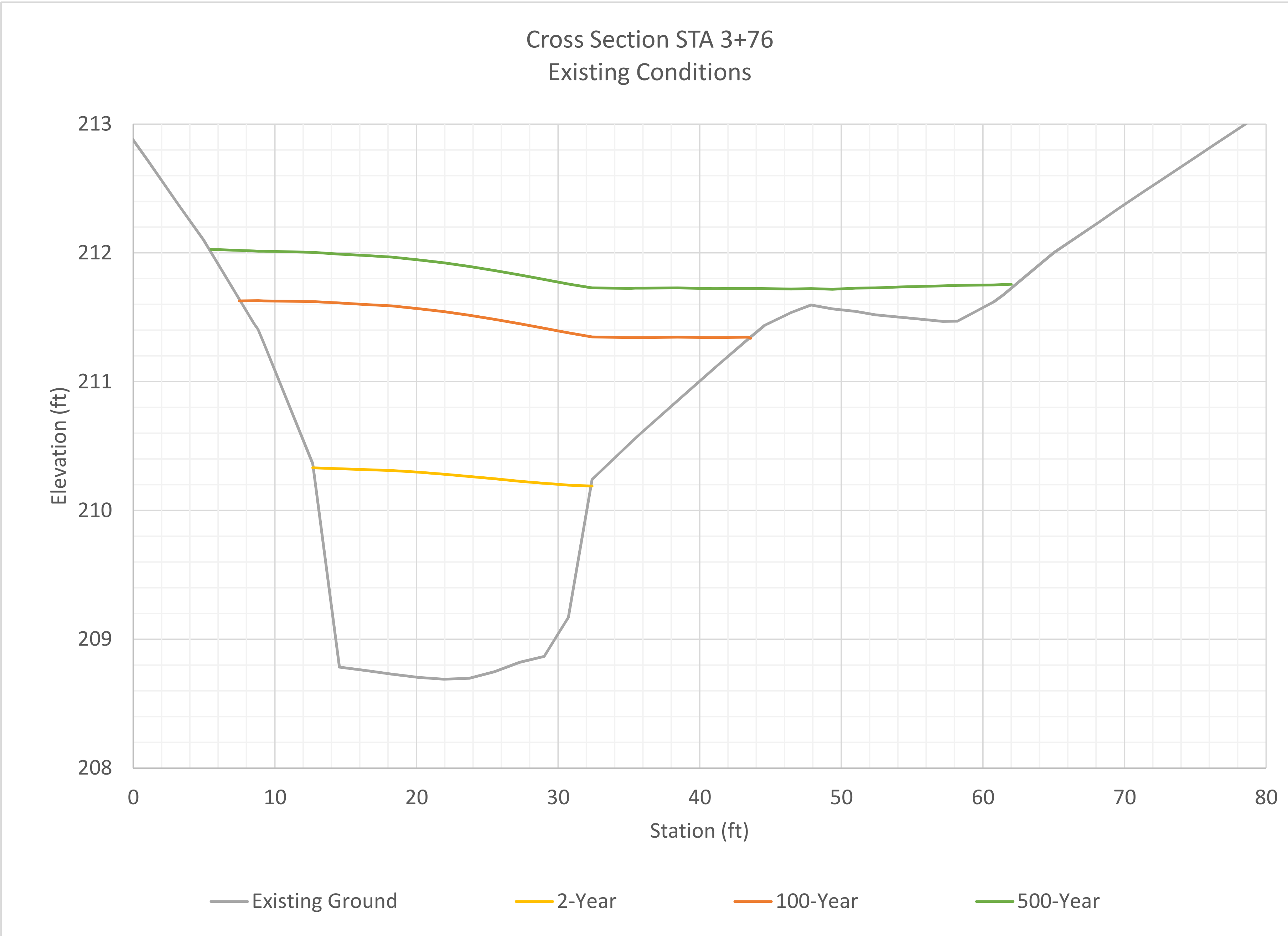
PROPOSED CONDITIONS 500-YEAR

SR 108 UNNAMED TRIBUTARY TO SKOOKUM CREEK
MP 5.54


Cross Section STA 3+23
Existing Conditions
213
212
211
210
209
208
207
Elevation (ft)
0
20
40
60
80
100
120
140
Station (ft)
Existing Ground
2-Year
100-Year
500-Year



Cross Section STA 3+23
Proposed Conditions
213
212
211
210
209
208
207
Elevation (ft)
0
20
40
60
80
100
120
140
Station (ft)
Existing Ground
2-Year
100-Year
100-Year Climate Change
500-Year


Cross Section STA 3+76
Existing Conditions
Elevation (ft)
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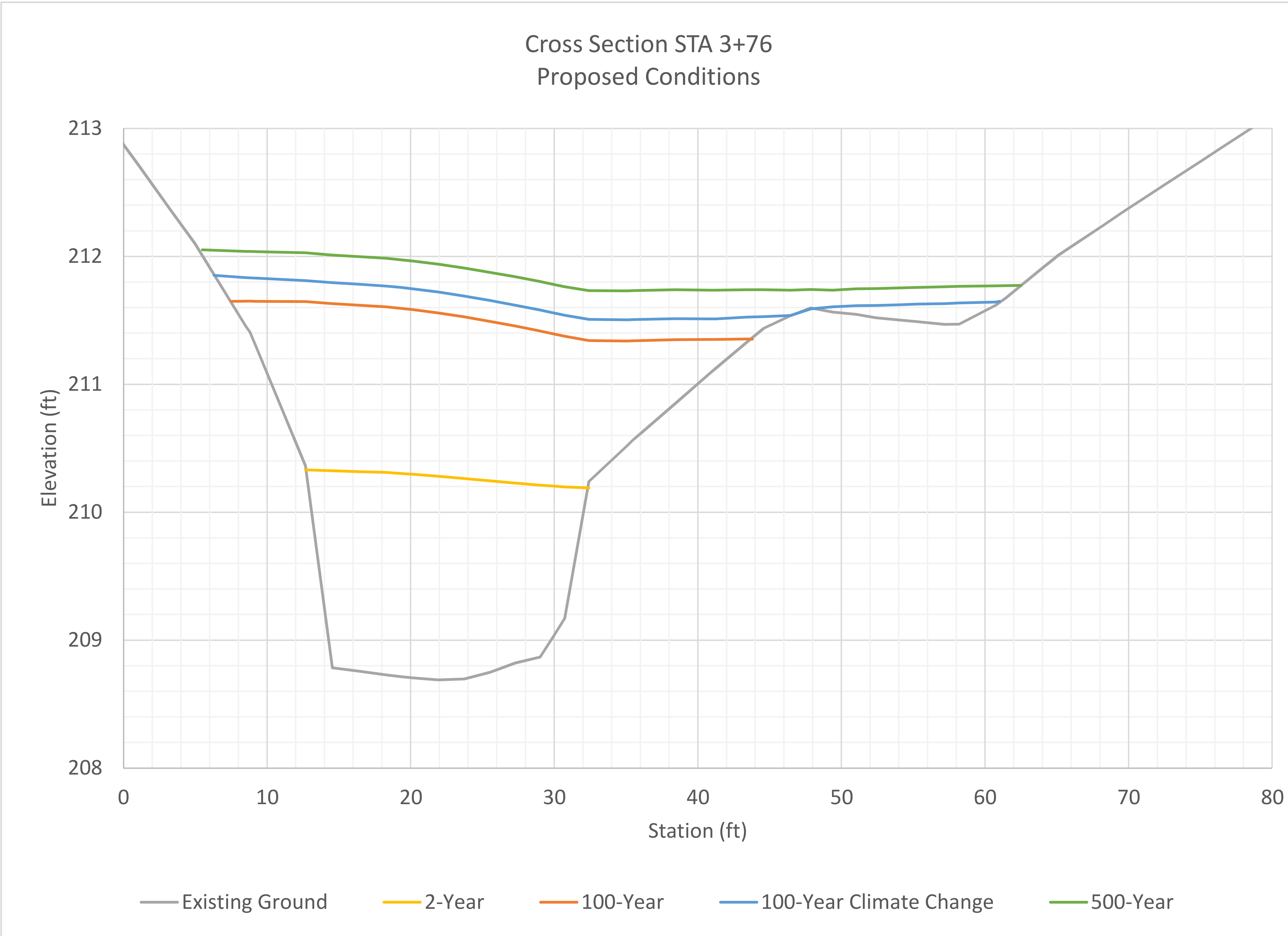
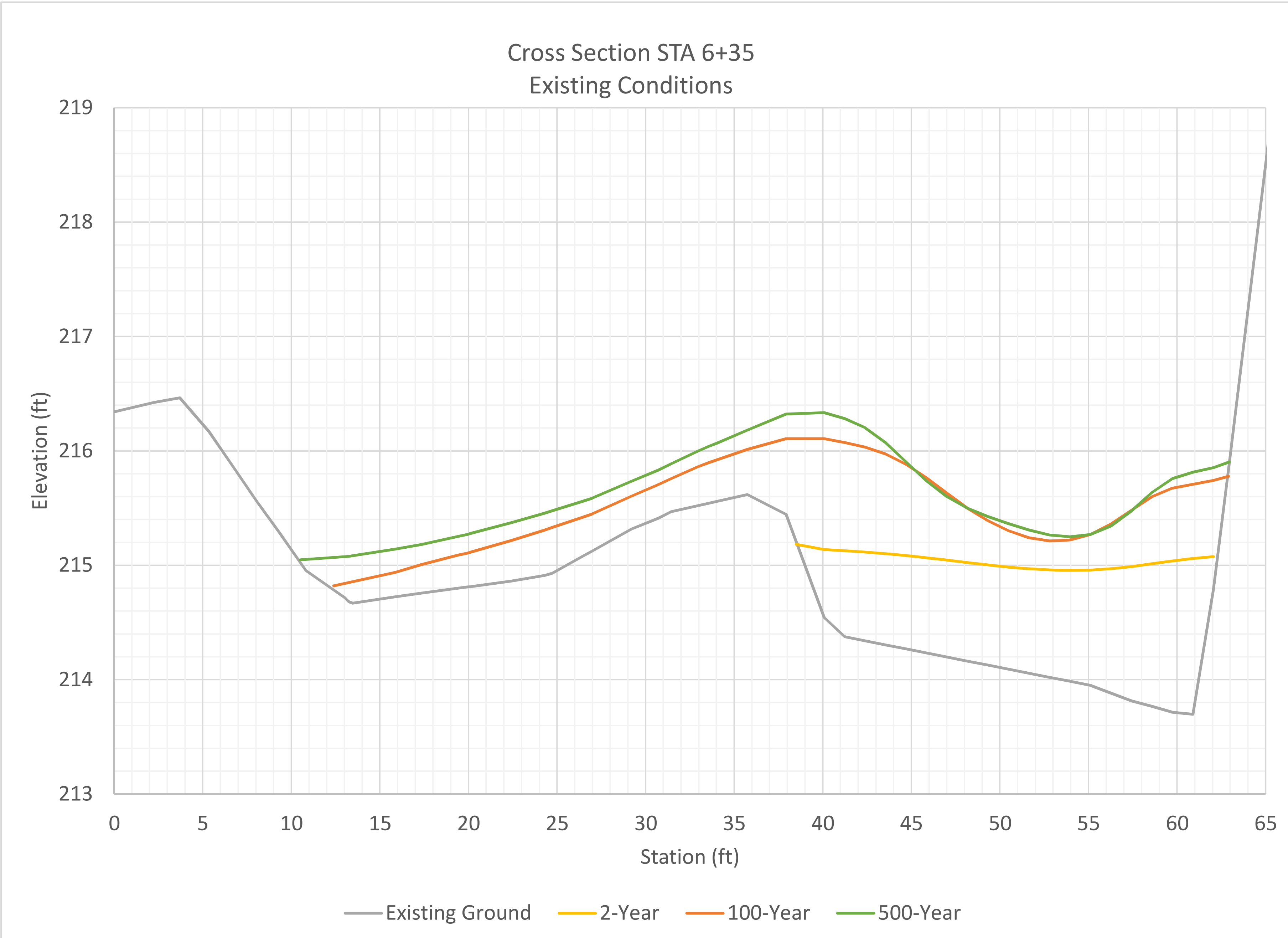
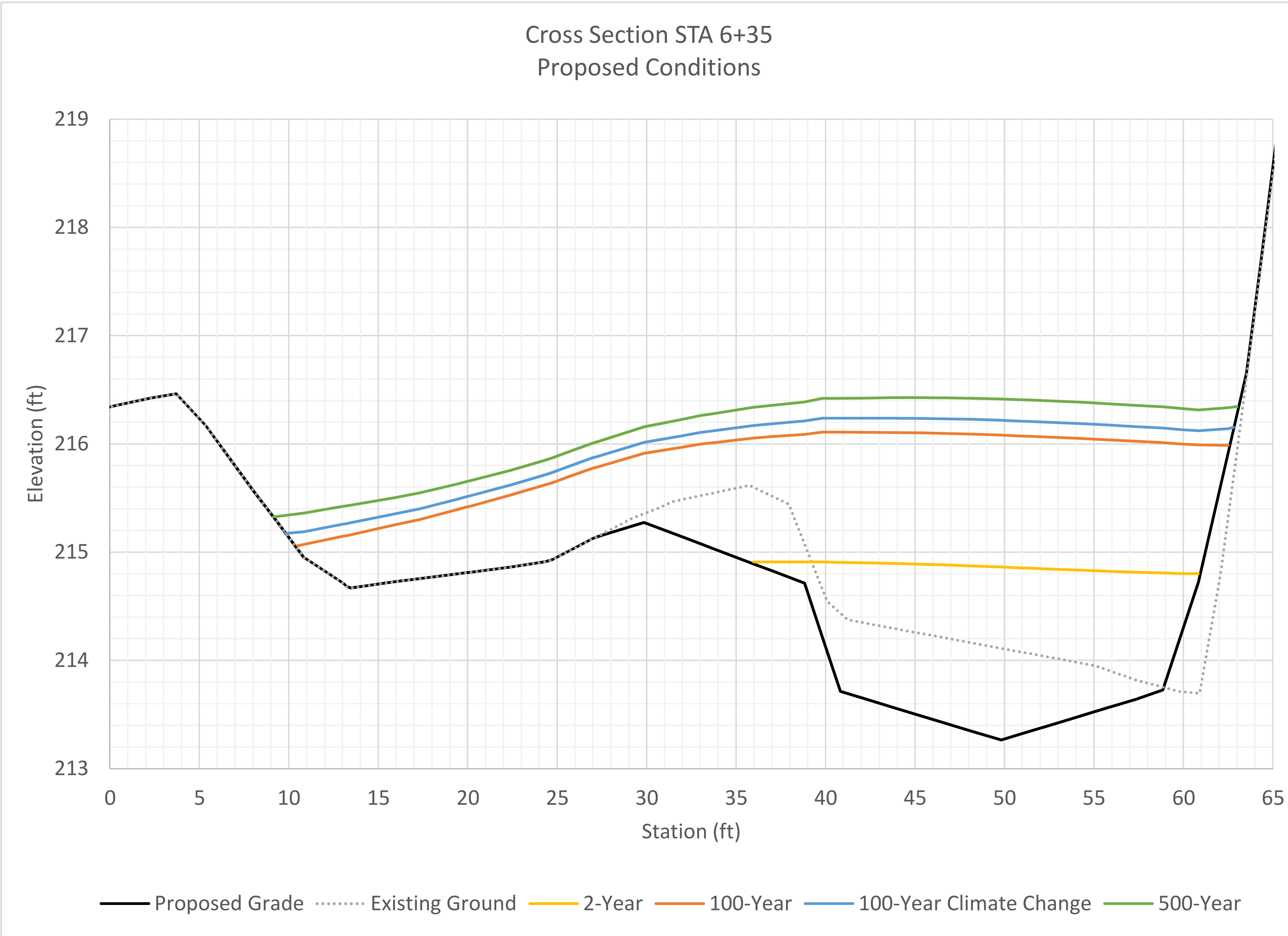
212
211
210
209
208
0
10
20
30
40
50
60
70
80
Station (ft)
Existing Ground
2-Year
100-Year
500-Year

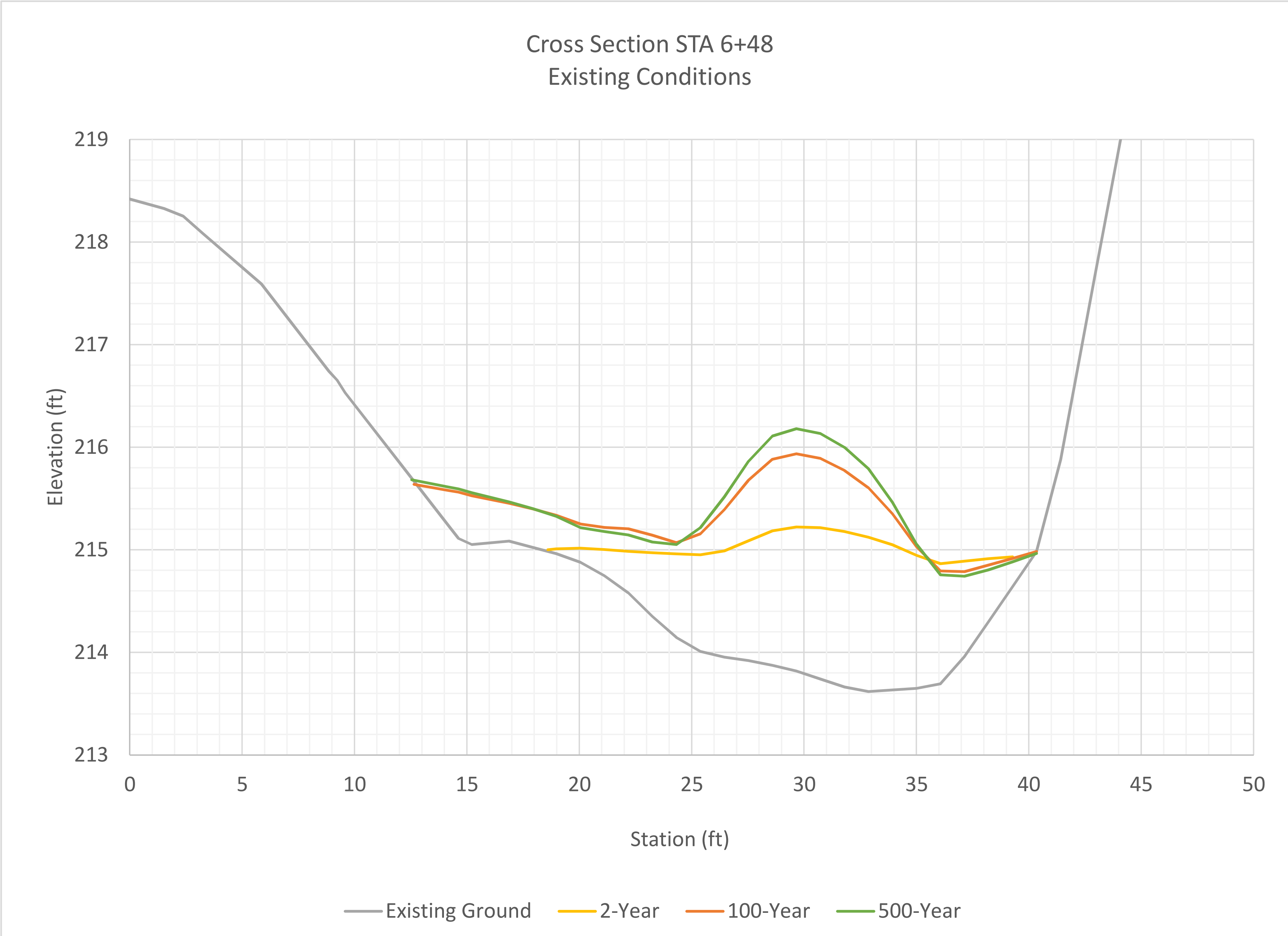


Cross Section STA 3+76
Proposed Conditions
213
212
211
210
209
208
Elevation (ft)
0
10
20
30
40
50
60
70
80
Station (ft)
Existing Ground
2-Year
100-Year
100-Year Climate Change
500-Year


Cross Section STA 6+35
Existing Conditions
Elevation (ft)
219
218
217
216
215
214
213
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Station (ft)
Existing Ground
2-Year
100-Year
500-Year



Cross Section STA 6+35
Proposed Conditions
Elevation (ft)
219
218
217
216
215
214
213
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Station (ft)
Proposed Grade
Existing Ground
2-Year
100-Year
100-Year Climate Change
500-Year



Cross Section STA 6+48
Existing Conditions
Elevation (ft)
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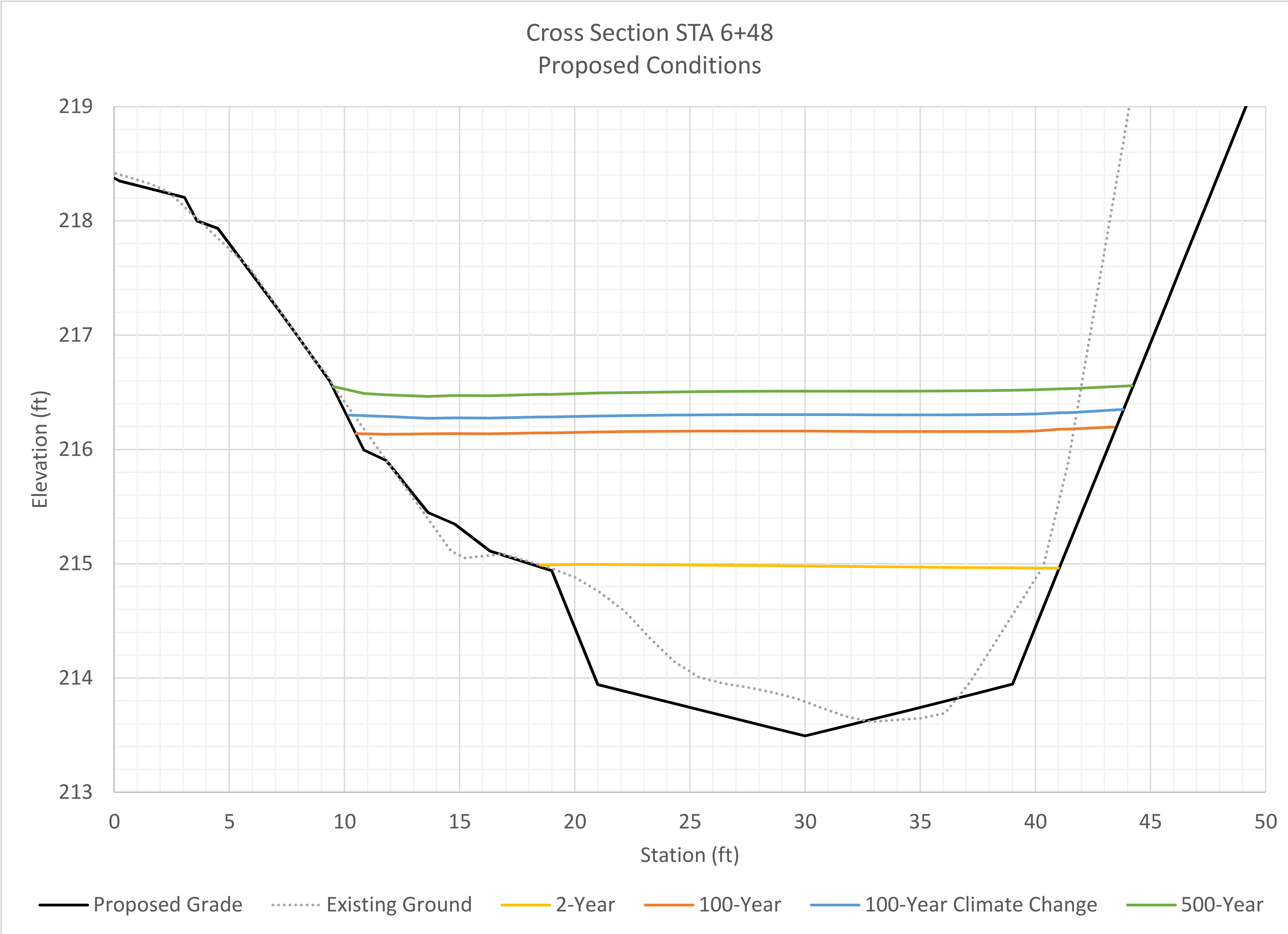
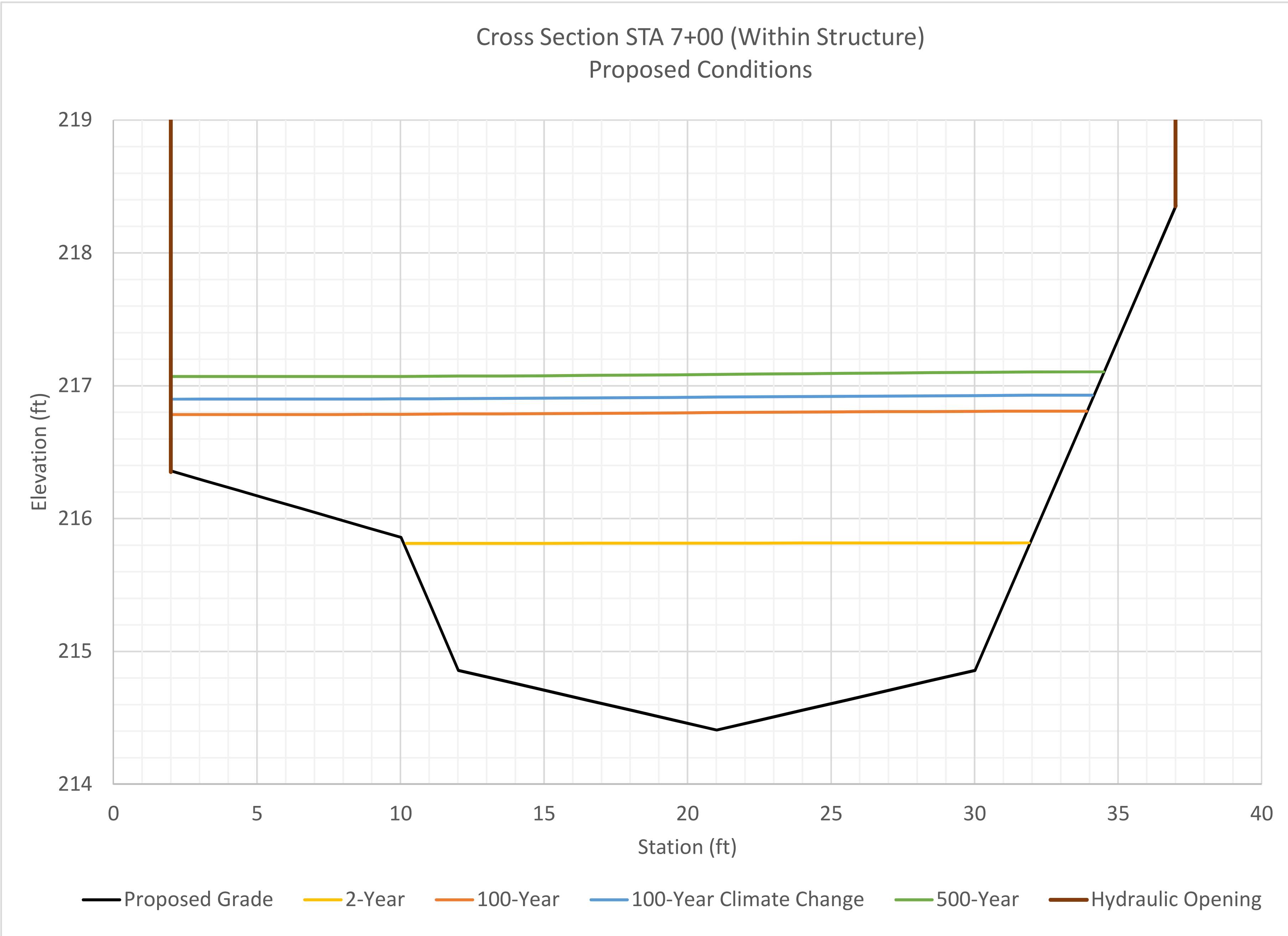
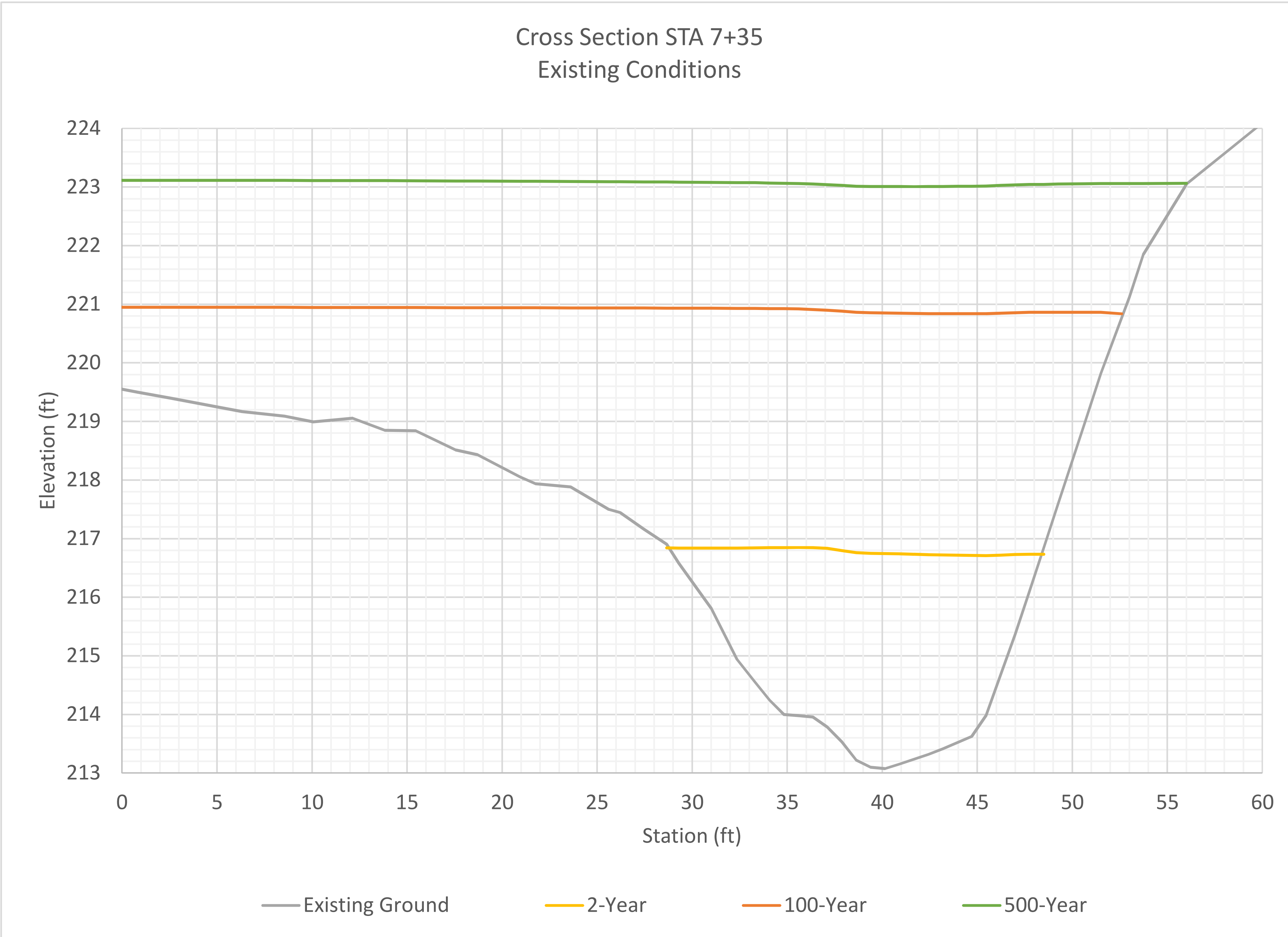
218
217
216
215
214
213
0
5
10
15
20
25
30
35
40
45
50
Station (ft)
Existing Ground
2-Year
100-Year
500-Year

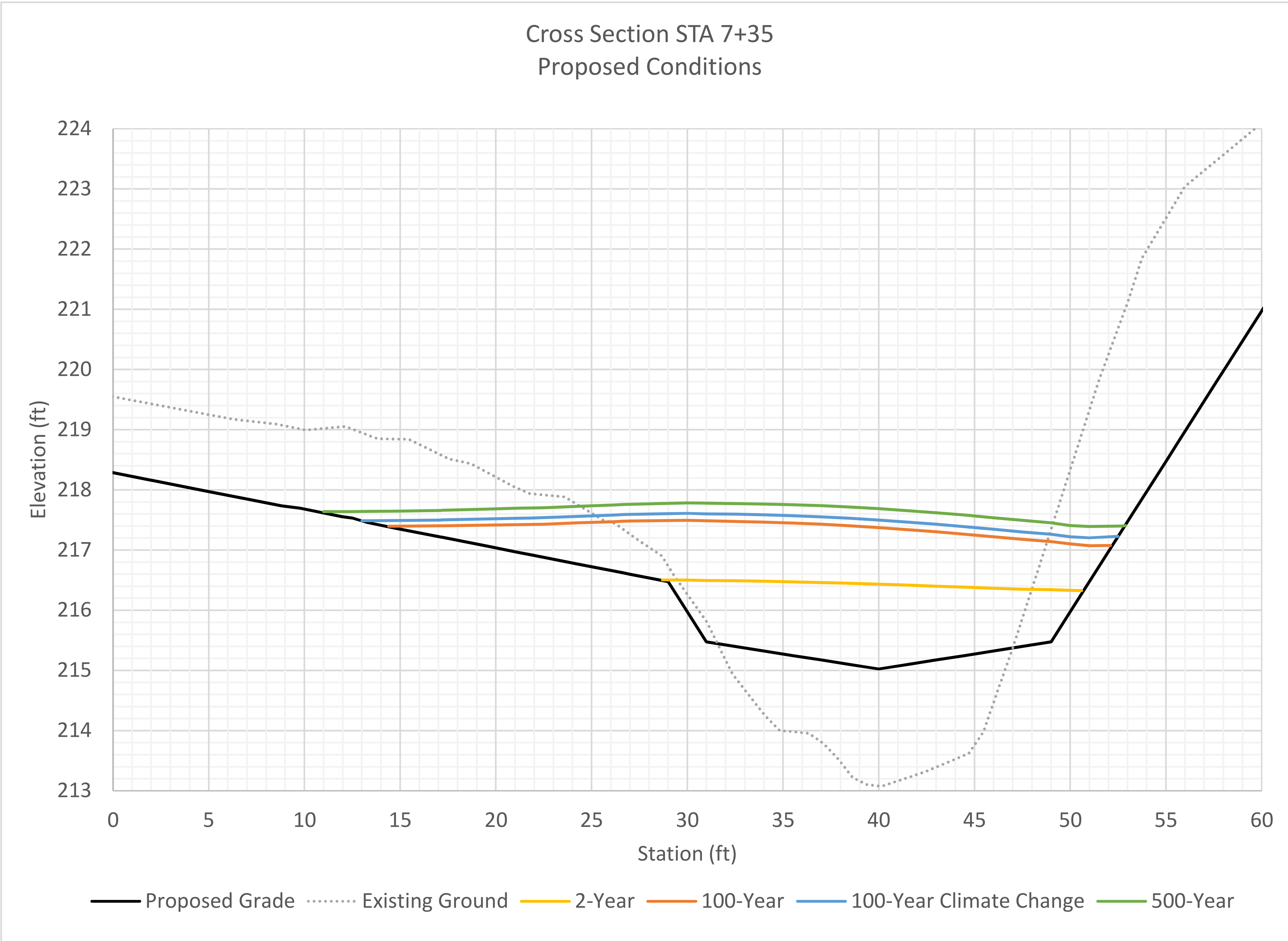


Cross Section STA 6+48
Proposed Conditions
Elevation (ft)
219
218
217
216
215
214
213
0
5
10
15
20
25
30
35
40
45
50
Station (ft)
Proposed Grade
Existing Ground
2-Year
100-Year
100-Year Climate Change
500-Year

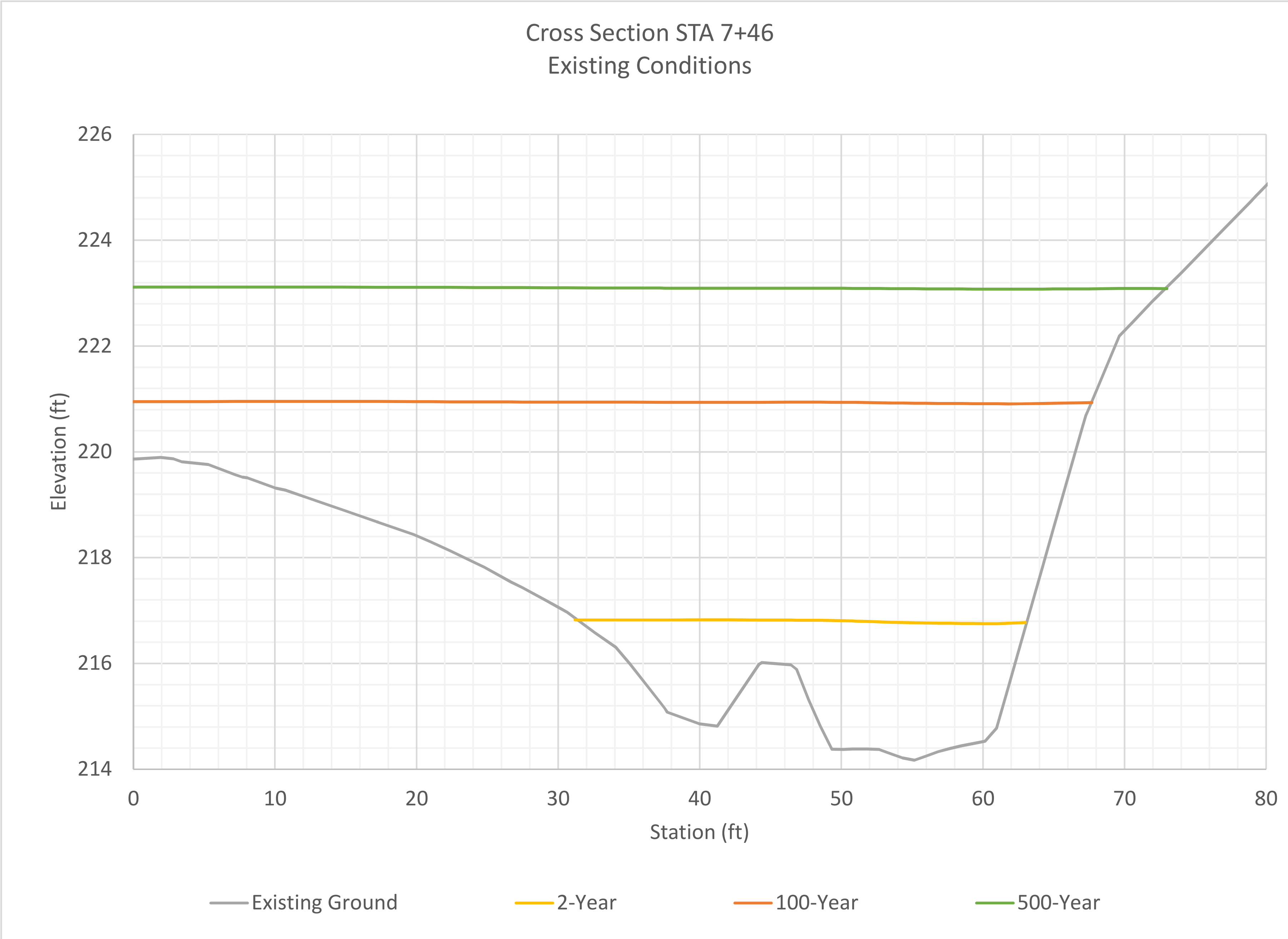

Cross Section STA 7+00 (Within Structure)
Proposed Conditions
219
218
217
216
215
214
Elevation (ft)
0
5
10
15
20
25
30
35
40
Station (ft)
Proposed Grade
2-Year
100-Year
100-Year Climate Change
500-Year
Hydraulic Opening



Cross Section STA 7+35
Existing Conditions
Elevation (ft)
224
223
222
221
220
219
218
217
216
215
214
213
0
5
10
15
20
25
30
35
40
45
50
55
60
Station (ft)
Existing Ground
2-Year
100-Year
500-Year



Cross Section STA 7+35
Proposed Conditions
Elevation (ft)
224
223
222
221
220
219
218
217
216
215
214
213
0
5
10
15
20
25
30
35
40
45
50
55
60
Station (ft)
Proposed Grade
Existing Ground
2-Year
100-Year
100-Year Climate Change
500-Year



Cross Section STA 7+46
Existing Conditions
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224
222
220
218
216
214
Elevation (ft)
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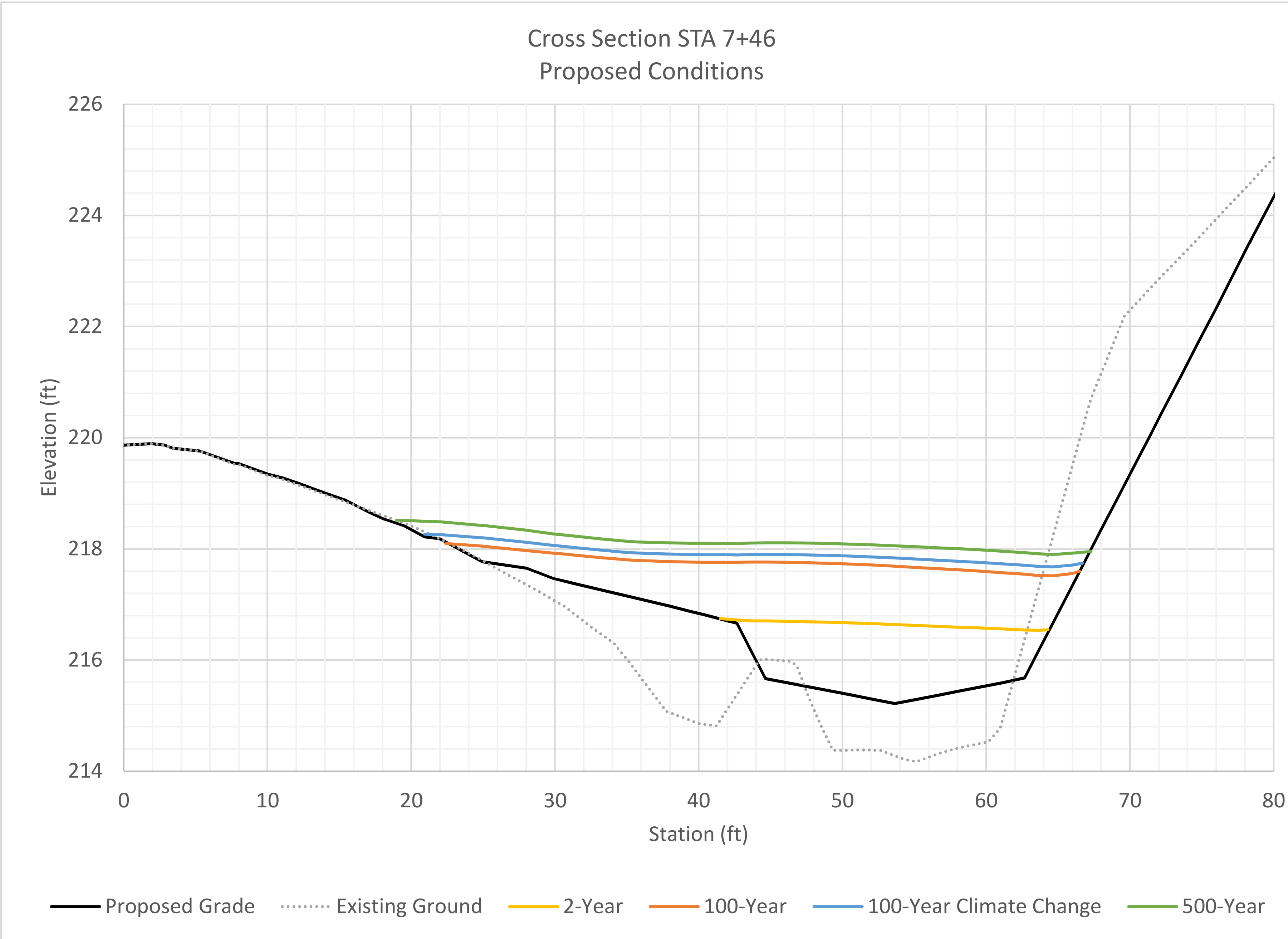
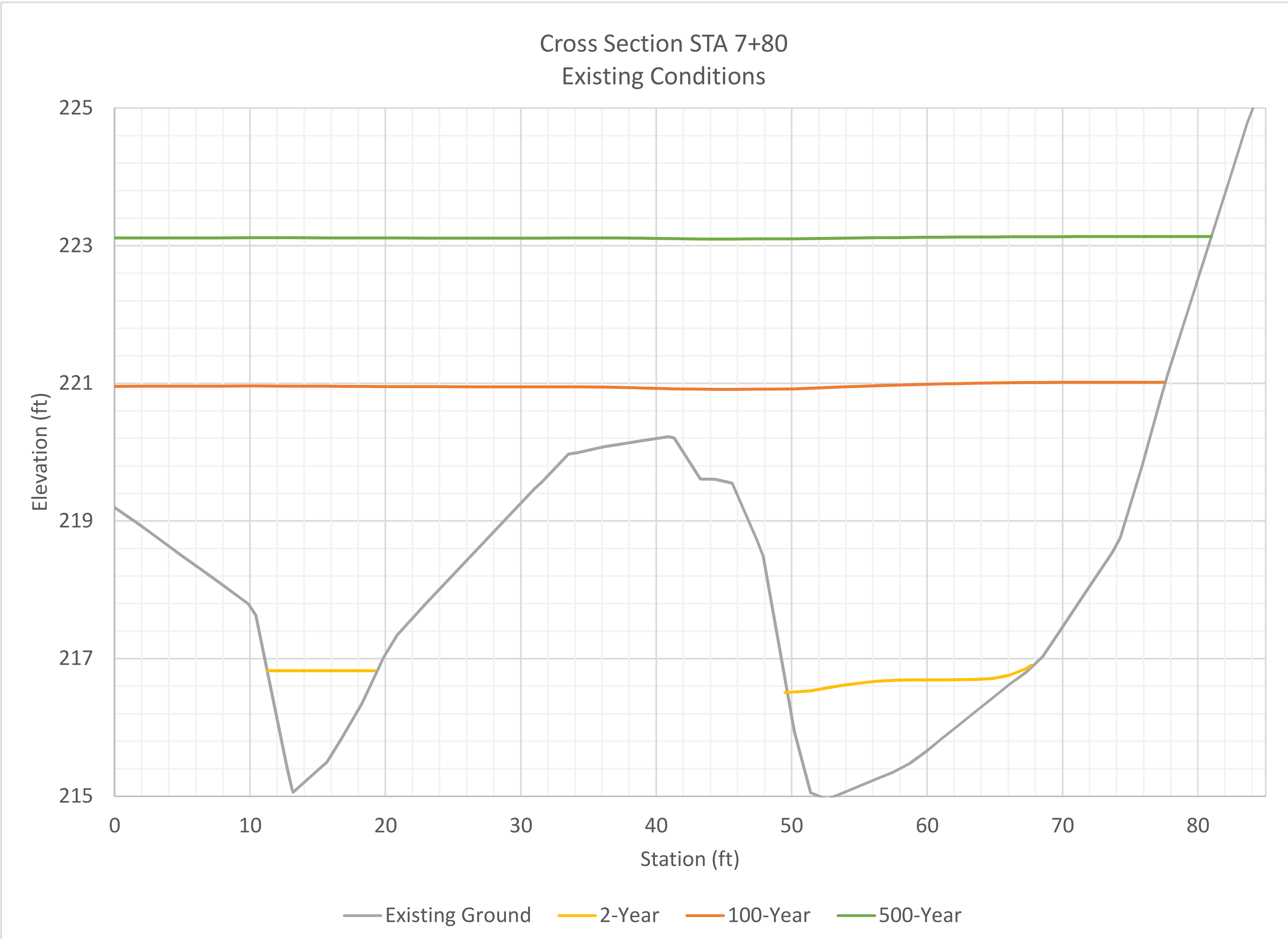
10
20
30
40
50
60
70
80
Station (ft)
Existing Ground
2-Year
100-Year
500-Year



Cross Section STA 7+46
Proposed Conditions
Elevation (ft)
Station (ft)
226
224
222
220
218
216
214
0
10
20
30
40
50
60
70
80
Proposed Grade
Existing Ground
2-Year
100-Year
100-Year Climate Change
500-Year


Cross Section STA 7+80
Existing Conditions
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223
221
219
217
215
Elevation (ft)
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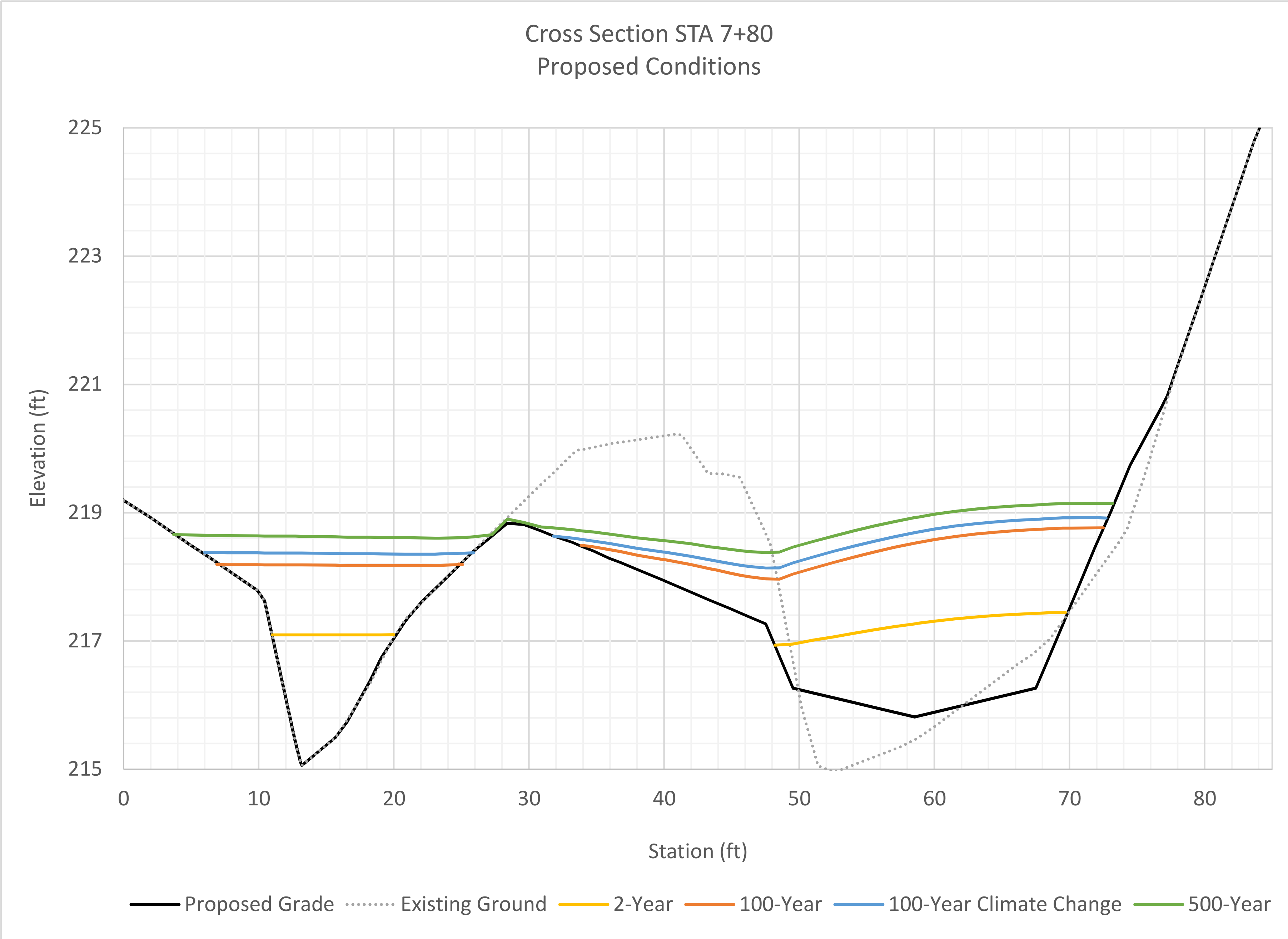
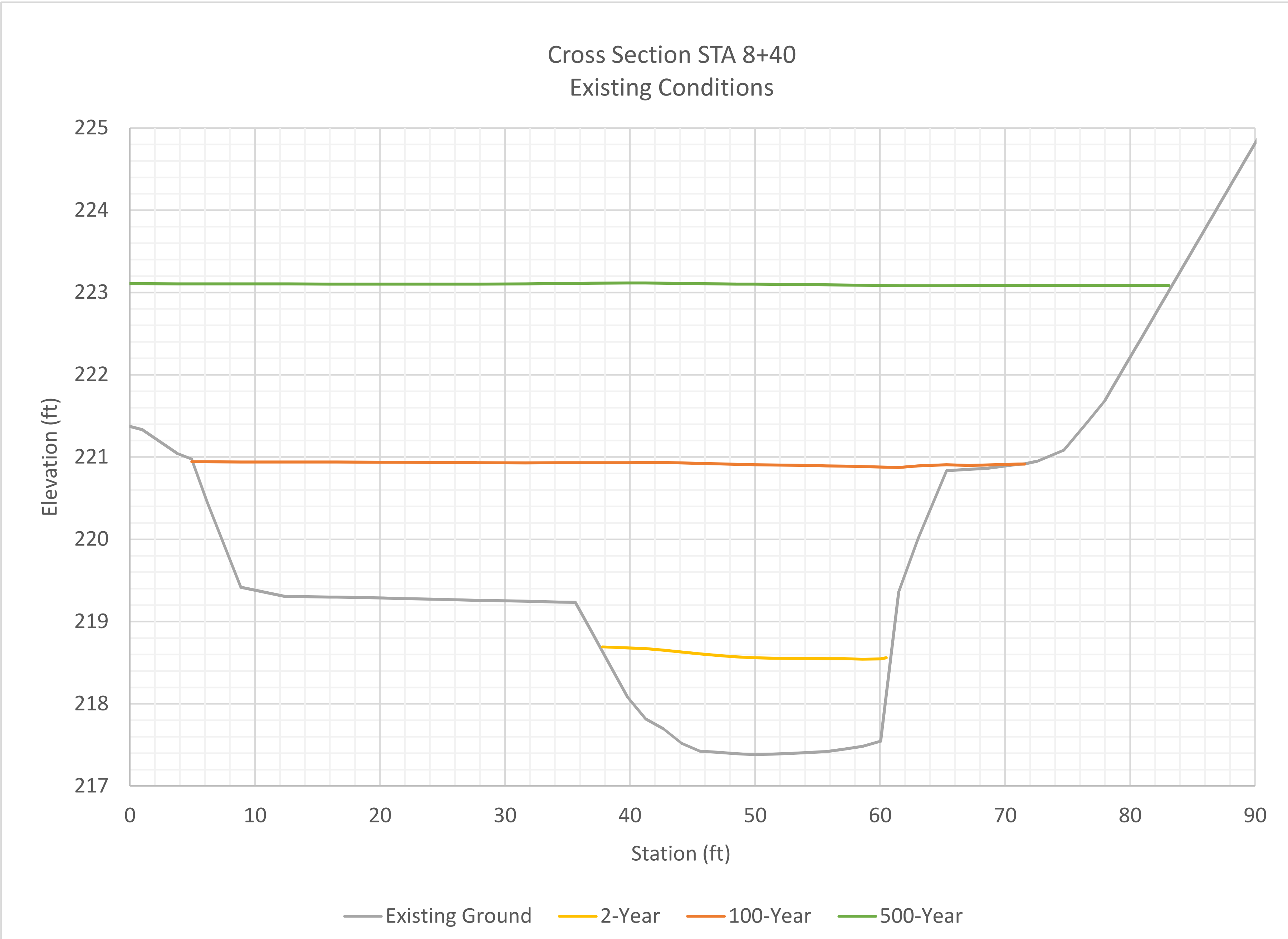
10
20
30
40
50
60
70
80
Station (ft)
Existing Ground
2-Year
100-Year
500-Year



Cross Section STA 7+80
Proposed Conditions
Elevation (ft)
225
223
221
219
217
215
0
10
20
30
40
50
60
70
80
Station (ft)
Proposed Grade
Existing Ground
2-Year
100-Year
100-Year Climate Change
500-Year



Cross Section STA 8+40
Existing Conditions
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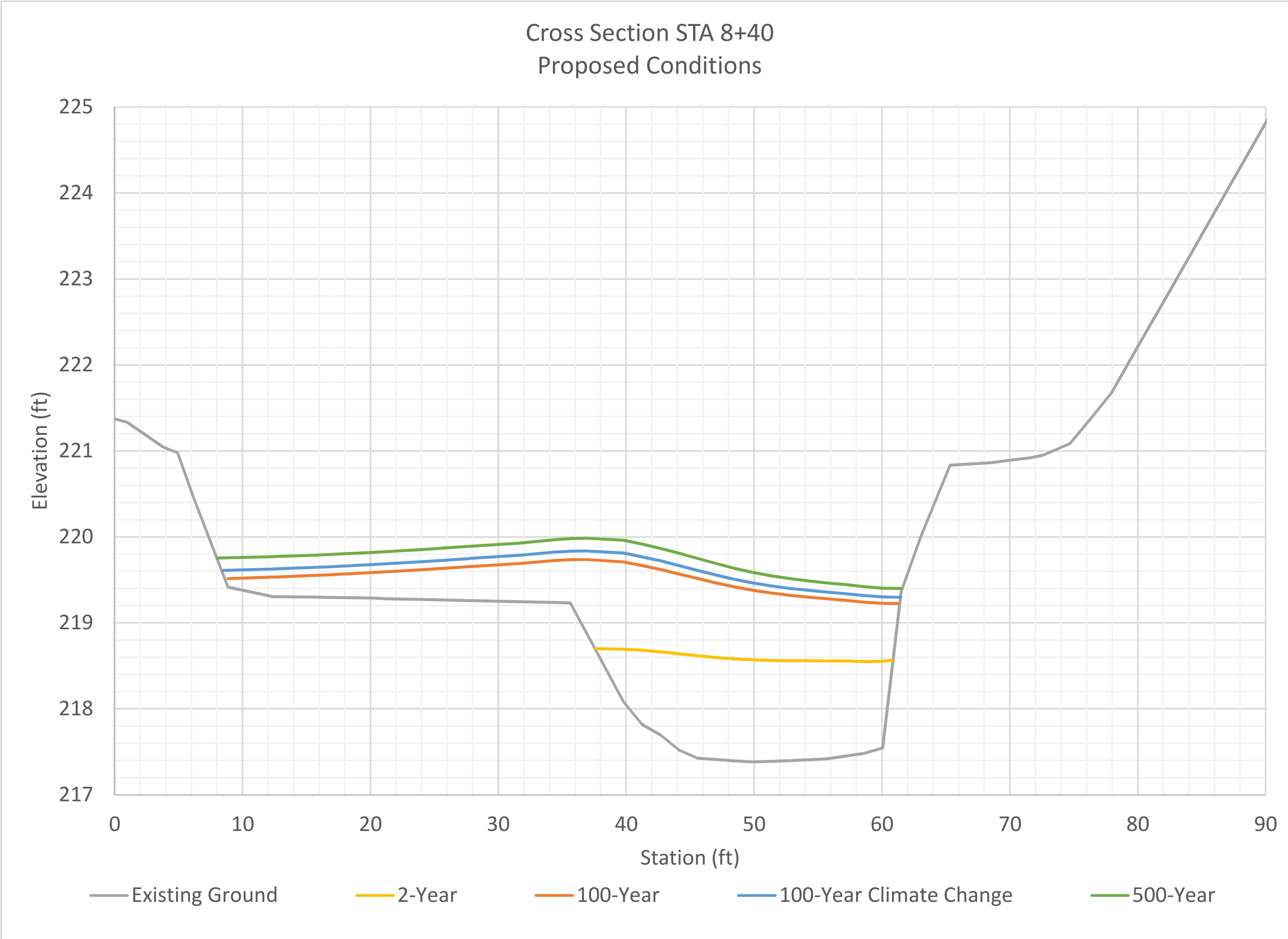
224
223
222
221
220
219
218
217
Elevation (ft)
0
10
20
30
40
50
60
70
80
90
Station (ft)
Existing Ground
2-Year
100-Year
500-Year


Cross Section STA 8+40
Proposed Conditions
Elevation (ft)
225
224
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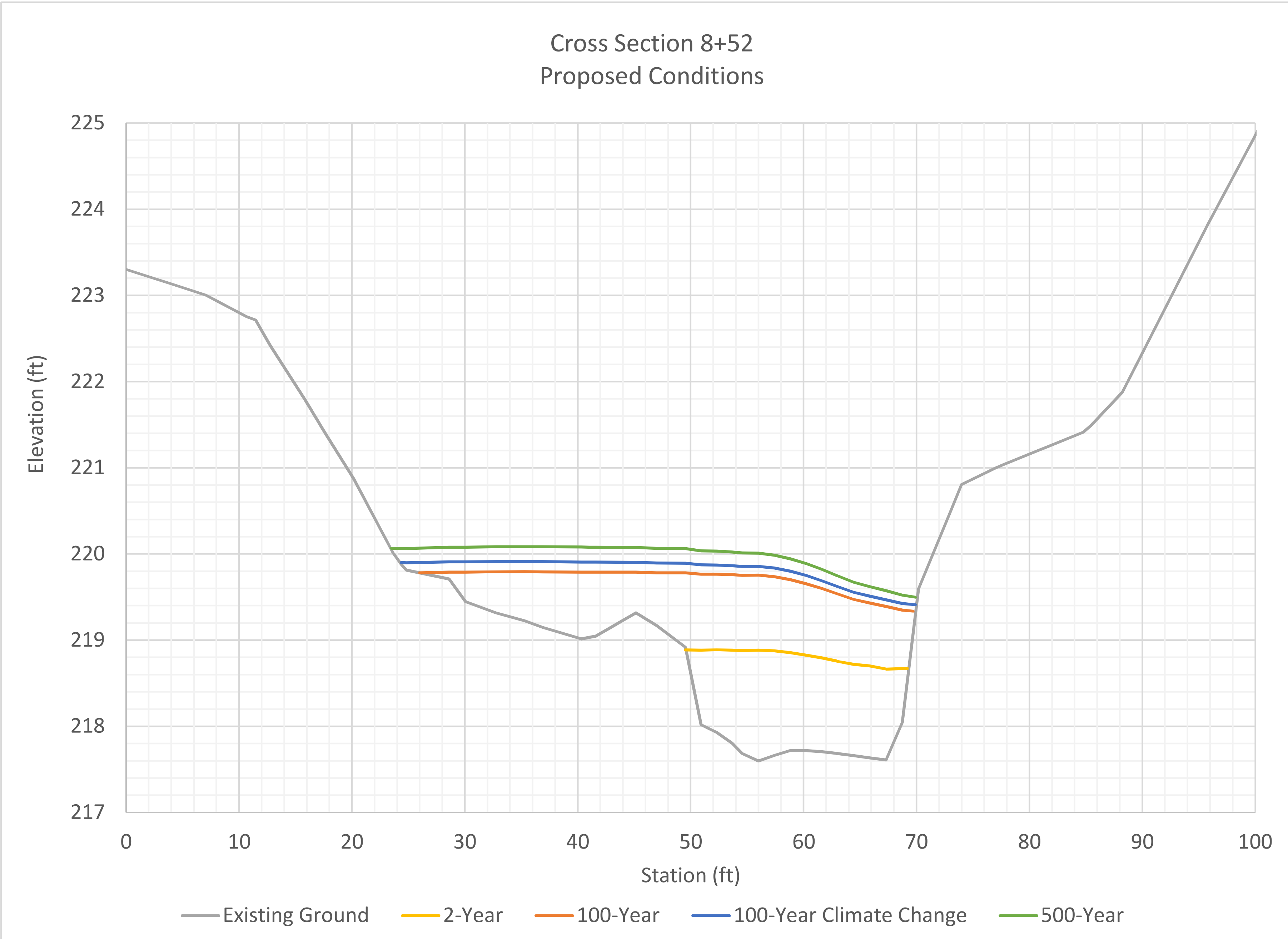
222
221
220
219
218
217
0
10
20
30
40
50
60
70
80
90
Station (ft)
Existing Ground
2-Year
100-Year
100-Year Climate Change
500-Year

Cross Section 8+52
Existing Conditions
Elevation (ft)
225
224
223
222
221
220
219
218
217
0
10
20
30
40
50
60
70
80
90
100
Station (ft)
Existing Ground
2-Year
100-Year
500-Year



Cross Section 8+52
Proposed Conditions
225
224
223
222
221
220
219
218
217
Elevation (ft)
0
10
20
30
40
50
60
70
80
90
100
Station (ft)
Existing Ground
2-Year
100-Year
100-Year Climate Change
500-Year

Appendix C: Streambed Material Sizing Calculations

Summary - Stream Simulation Bed Material Design

Project:	WSDOT SR 108 MP 5.54
By:	Grace Doran

Design Gradation:				
Location:	Streambed Design			
	D_{100}	D_{84}	D_{50}	D_{16}
ft	1.8	0.2	0.1	0.03
in	21.3	2.8	1.2	0.4
mm	541	71	30.7	10.4

Determining Aggregate Proportions

Per WSDOT Standard Specifications 9-03.11

Rock Size [in]	[mm]	Streambed Sediment	Streambed Cobbles 4"	6"	8"	10"	12"	Streambed Boulders 12"-18"	18"-28"	28"-36"	D_{size}
36.0	914									100	100.0
32.0	813									50	100.0
28.0	711								100		100.0
23.0	584								50		100.0
18.0	457							100			100.0
15.0	381							50			100.0
12.0	305						100				100.0
10.0	254					100	80				100.0
8.0	203				100	80	68				100.0
6.0	152			100	80	68	57				100.0
5.0	127			80	68	57	45				92.0
4.0	102		100	71	57	45	39				88.5
3.0	76.2		80	63	45	38	34				85.0
2.5	63.5	100	65	54	37	32	28				81.5
2.0	50.8	80	50	45	29	25	22				66.0
1.5	38.1	73	35	32	21	18	16				56.2
1.0	25.4	65	20	18	13	12	11				46.3
0.75	19.1	50	5	5	5	5	5				32.0
0.187	4.75	35									21.0
No. 40 =	0.425	16									9.6
No. 200 =	0.0750	7									4.2
% per category		60		40		0	0	0	0	0	--> 100%

Streambed Mobility/Stability Analysis

Modified Shields Approach

References:

Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organizms at Road-Stream Crossings

Appendix E--Methods for Streambed Mobility/Stability Analysis

Limitations:

D_{84} must be between 0.40 in and 10 in

uniform bed material (Di < 20-30 times D50)

Slopes less than 5%

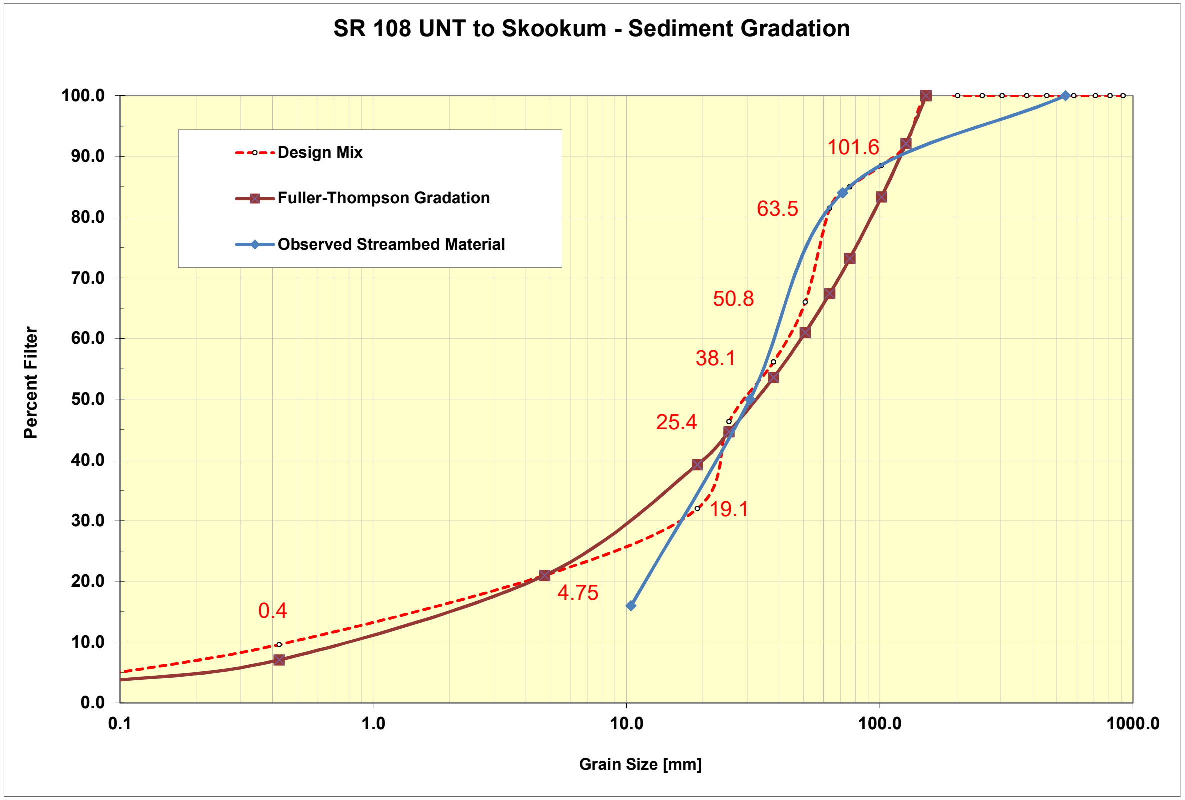
Sand/gravel streams with high relative submergence

γ_s	165	specific weight of sediment particle (lb/ft^3)
γ	62.4	specific weight of water (1b/ft^3)
τ_{D50}	0.047	dimensionless Shields parameter for D50

Flow	2-YR (109 cfs)	25-YR (254 cfs)	50-YR (288 cfs)	100-YR (326 cfs)	500-YR (413 cfs)
Average Modeled Shear Stress (lb/ft^2)	1.2	2.1	2.2	2.4	2.6
τ_{ci}					
1.31	No Motion	Motion	Motion	Motion	Motion
1.26	No Motion	Motion	Motion	Motion	Motion
1.21	No Motion	Motion	Motion	Motion	Motion
1.14	Motion	Motion	Motion	Motion	Motion
1.06	Motion	Motion	Motion	Motion	Motion
1.01	Motion	Motion	Motion	Motion	Motion
0.94	Motion	Motion	Motion	Motion	Motion
0.89	Motion	Motion	Motion	Motion	Motion
0.83	Motion	Motion	Motion	Motion	Motion
0.76	Motion	Motion	Motion	Motion	Motion
0.72	Motion	Motion	Motion	Motion	Motion
0.68	Motion	Motion	Motion	Motion	Motion
0.62	Motion	Motion	Motion	Motion	Motion
0.59	Motion	Motion	Motion	Motion	Motion
0.55	Motion	Motion	Motion	Motion	Motion
0.50	Motion	Motion	Motion	Motion	Motion
0.45	Motion	Motion	Motion	Motion	Motion
0.41	Motion	Motion	Motion	Motion	Motion
0.27	Motion	Motion	Motion	Motion	Motion

	D95	D84	D50	D35	D16
Mix Size Interpolation	95	84	50	35	16
(mm)	136	72	30	20	2
(inches)	5.35	2.85	1.16	0.80	0.06
(feet)	0.45	0.24	0.10	0.07	0.01

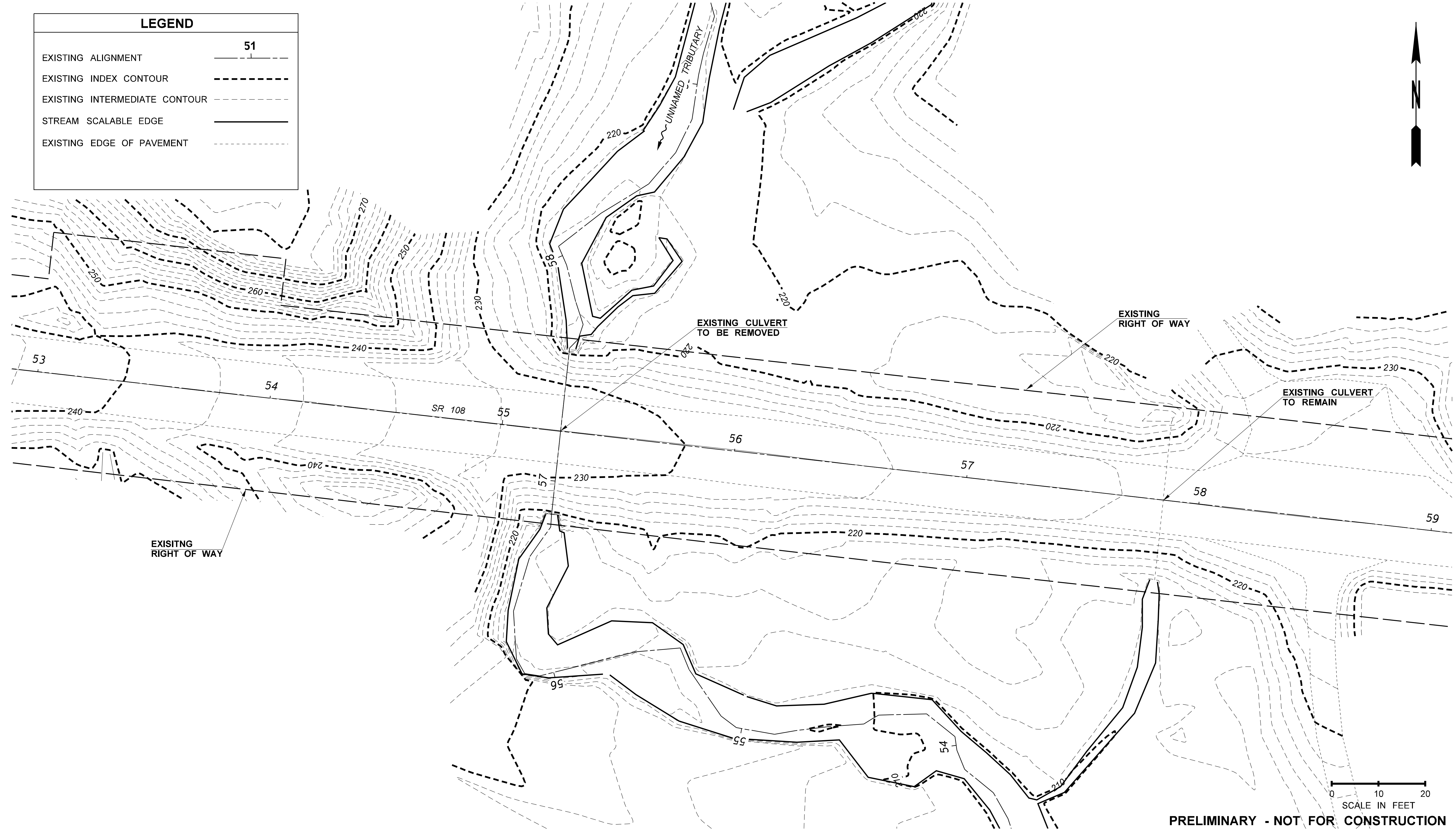
Otto Gershon, gershoo@wsdot.wa.gov ; 9/2007
modified by Kevin Lautz, P.E. 6/2010



Otto Gershon, gershoo@wsdot.wa.gov ; 9/2007
modified by Kevin Lautz, P.E. 6/2010

Appendix D: Stream Plan Sheets, Profile, Details

T.19N. R.4E. W.M.



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DESIGNED BY	S. BEVAN
ENTERED BY	K. LA TORRE A.
CHECKED BY	J. HEILMAN
PROJ. ENGR.	
REGIONAL ADM.	J. WYNANDS

REVISION | DATE | BY

REGION NO. 10 | STATE WASH | FED.AID PROJ.NO.

JOB NUMBER XXXXX

CONTRACT NO. | LOCATION NO. XL12331

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State Department of Transportation

HDR

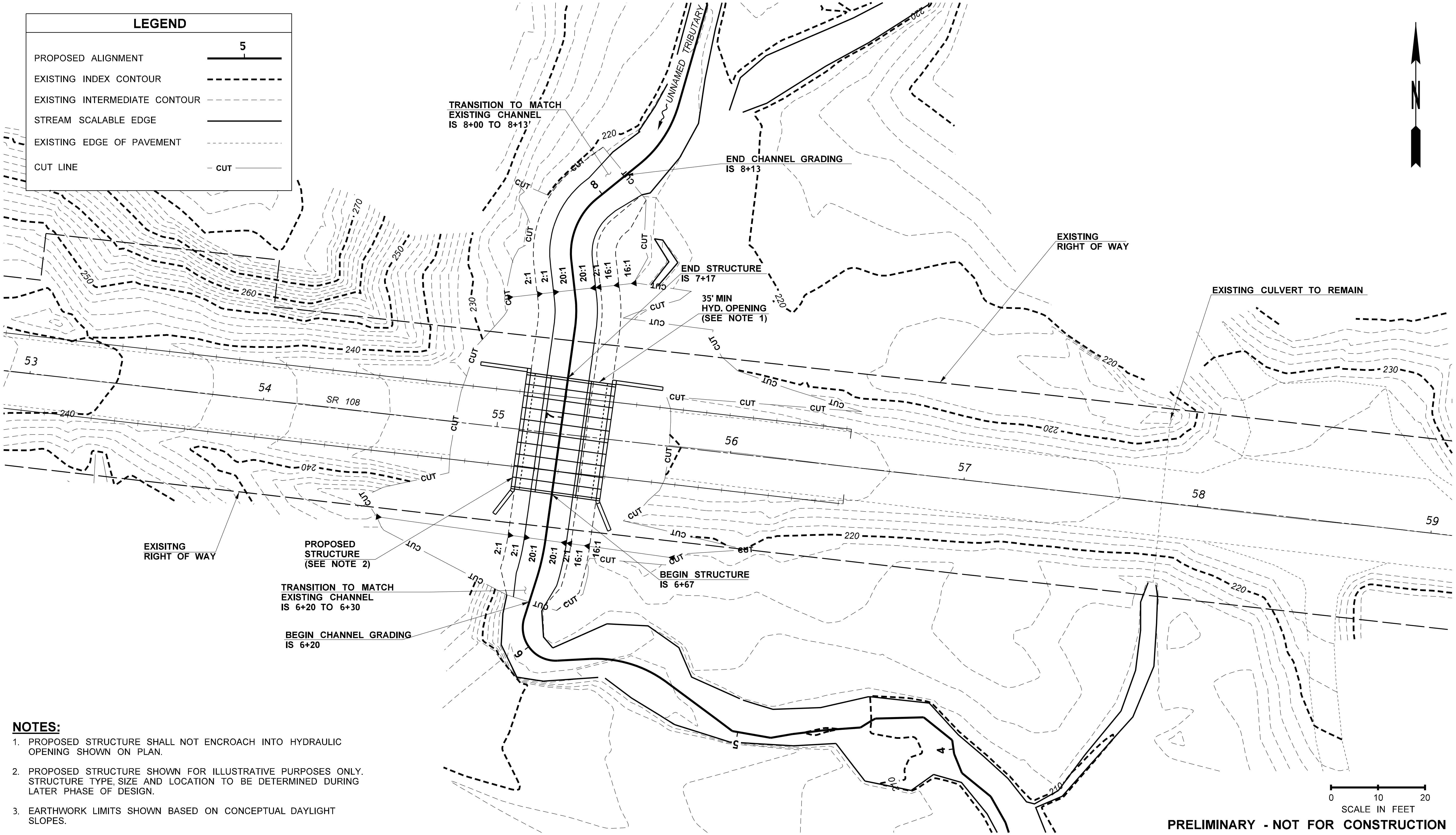
SR 108 MP 5.54
UNNAMED TRIBUTARY TO SKOOKUM CREEK
FISH BARRIER REMOVAL

EXISTING STREAM PLAN

PLAN REF NO CE1

SHEET 1 OF 4 SHEETS

T.19N. R.4E. W.M.



LEGEND

PROPOSED ALIGNMENT	5
EXISTING INDEX CONTOUR	
EXISTING INTERMEDIATE CONTOUR	
STREAM SCALABLE EDGE	
EXISTING EDGE OF PAVEMENT	
CUT LINE	CUT

NOTES:

1. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO HYDRAULIC OPENING SHOWN ON PLAN.
2. PROPOSED STRUCTURE SHOWN FOR ILLUSTRATIVE PURPOSES ONLY. STRUCTURE TYPE, SIZE AND LOCATION TO BE DETERMINED DURING LATER PHASE OF DESIGN.
3. EARTHWORK LIMITS SHOWN BASED ON CONCEPTUAL DAYLIGHT SLOPES.

PRELIMINARY - NOT FOR CONSTRUCTION

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DESIGNED BY	S. BEVAN
ENTERED BY	K. LA TORRE A.
CHECKED BY	J. HEILMAN
PROJ. ENGR.	
REGIONAL ADM.	J. WYNANDS

REVISION	DATE	BY

REGION NO. 10 | STATE WASH | FED.AID PROJ.NO.
JOB NUMBER XXXXX
CONTRACT NO. | LOCATION NO. XL12331

P.E. STAMP BOX DATE
P.E. STAMP BOX DATE

Washington State Department of Transportation

HDR

SR 108 MP 5.54
UNNAMED TRIBUTARY TO SKOOKUM CREEK
FISH BARRIER REMOVAL

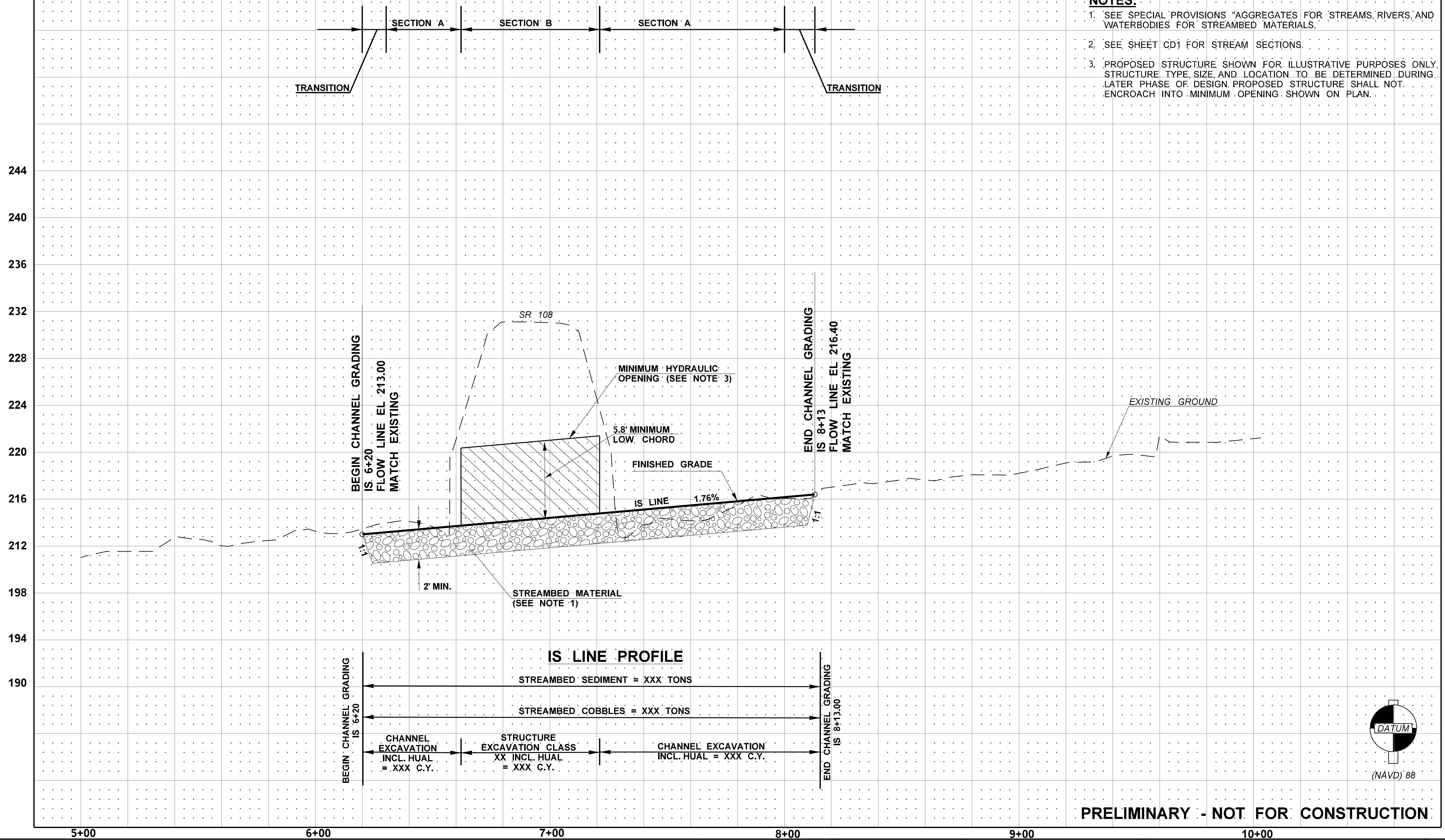
STREAM PLAN

PLAN REF NO CR1

SHEET 2 OF 4 SHEETS

NOTES:

1. SEE SPECIAL PROVISIONS "AGGREGATES FOR STREAMS, RIVERS, AND WATERBODIES FOR STREAMBED MATERIALS.
2. SEE SHEET CD1 FOR STREAM SECTIONS.
3. PROPOSED STRUCTURE SHOWN FOR ILLUSTRATIVE PURPOSES ONLY, STRUCTURE TYPE, SIZE, AND LOCATION TO BE DETERMINED DURING LATER PHASE OF DESIGN. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO MINIMUM OPENING SHOWN ON PLAN.



PRELIMINARY - NOT FOR CONSTRUCTION

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DATE	5/29/2020						
PLOTTED BY	LGREBE			JOB NUMBER XXXXX			
DESIGNED BY	S. BEVAN						
ENTERED BY	K. LA TORRE A.						
CHECKED BY	J. HEILMAN			CONTRACT NO.		LOCATION NO. XL12331	
PROJ. ENGR.							
REGIONAL ADM.	J. WYNANDS	REVISION	DATE	BY			

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State Department of Transportation

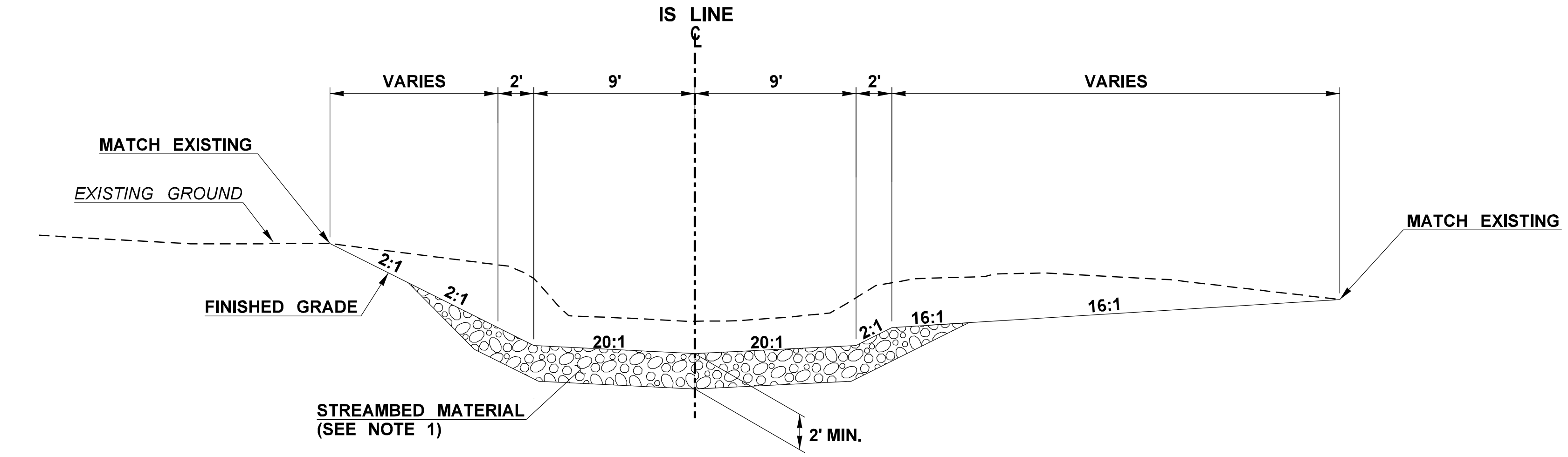
HDR

SR 108 MP 5.54
UNNAMED TRIBUTARY TO SKOOKUM CREEK
FISH BARRIER REMOVAL

STREAM PROFILE

PLAN REF. NO. CP1

SHEET 3 OF 4 SHEETS



SECTION A

STATION
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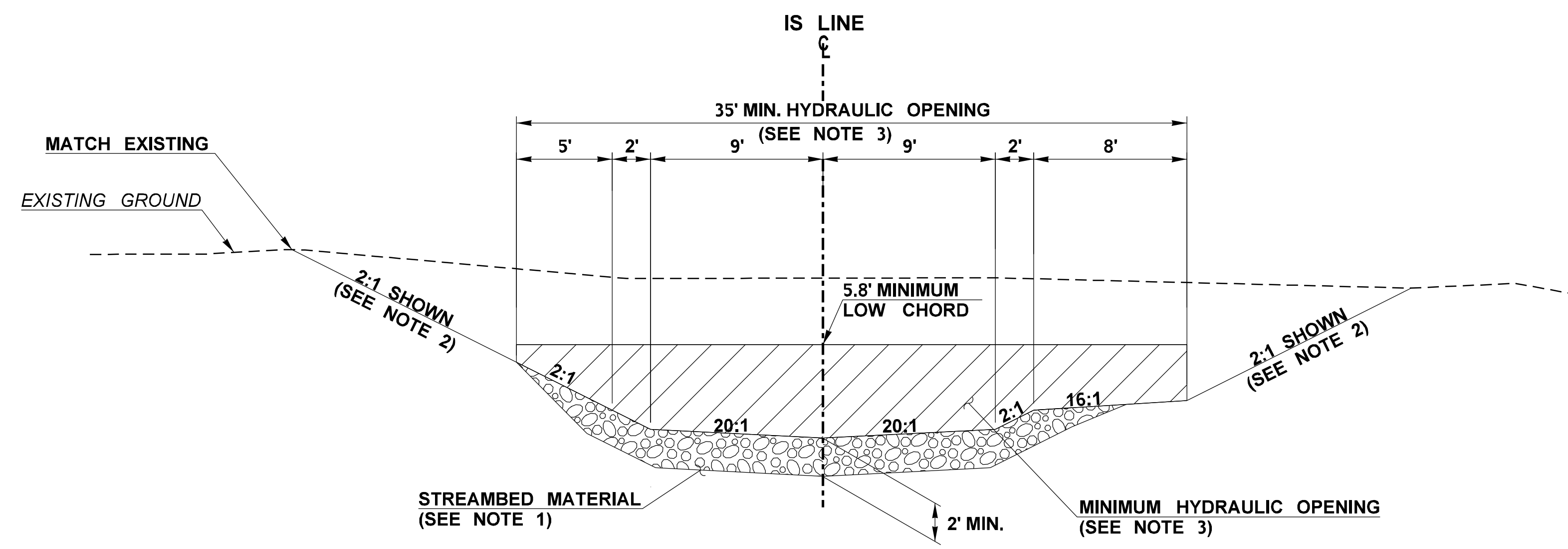
IS 7+20 TO 8+00



SECTION B

STATION
IS 6+60 TO 7+20

NOTES:

1. SEE SPECIAL PROVISIONS "AGGREGATE FOR STREAMS, RIVERS, AND WATERBODIES" FOR STREAMBED MATERIAL.
2. SLOPES SHOWN OUTSIDE HYDRAULIC OPENING ARE FOR ILLUSTRATIVE PURPOSES ONLY TO DEPICT ESTIMATED AREA OF POTENTIAL IMPACT. FINAL AREAS OF IMPACT TO BE DETERMINED PENDING GEOLOGICAL AND STRUCTURAL INVESTIGATION, STRUCTURE TYPE AND STRUCTURE LOCATION.
3. PROPOSED STRUCTURE SHALL NOT ENCROACH INTO MINIMUM OPENING SHOWN ON PLAN. THE MINIMUM HYDRAULIC OPENING IS NOT CENTERED ON THE STREAM CENTERLINE.

PRELIMINARY - NOT FOR CONSTRUCTION

FILE NAME	c:\users\lgrebe\pw_wsdot\d0307078\XL123331_I_DE_CD_PHD.dgn
TIME	11:13:42 AM
DATE	5/29/2020
PLOTTED BY	LGREBE
DESIGNED BY	S. BEVAN
ENTERED BY	K. LA TORRE A.
CHECKED BY	J. HEILMAN
PROJ. ENGR.	
REGIONAL ADM.	J. WYNANDS

REVISION	DATE	BY

REGION NO.	STATE	FED.AID PROJ.NO.
10	WASH	
JOB NUMBER XXXXX		
CONTRACT NO.		LOCATION NO. XL12331

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State Department of Transportation

HDR

SR 108 MP 5.54
UNNAMED TRIBUTARY TO SKOOKUM CREEK
FISH BARRIER REMOVAL

STREAM DETAILS

PLAN REF NO CD1

SHEET 4 OF 4 SHEETS

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Appendix E: WDFW Climate Change Analysis

Future Projections for Climate-Adapted Culvert Design

Project Name: 990385

Stream Name: UNT to Skookum Creek

Drainage Area: 997 ac

Projected mean percent change in bankfull flow:

2040s: 15%

2080s: 21.7%

Projected mean percent change in bankfull width:

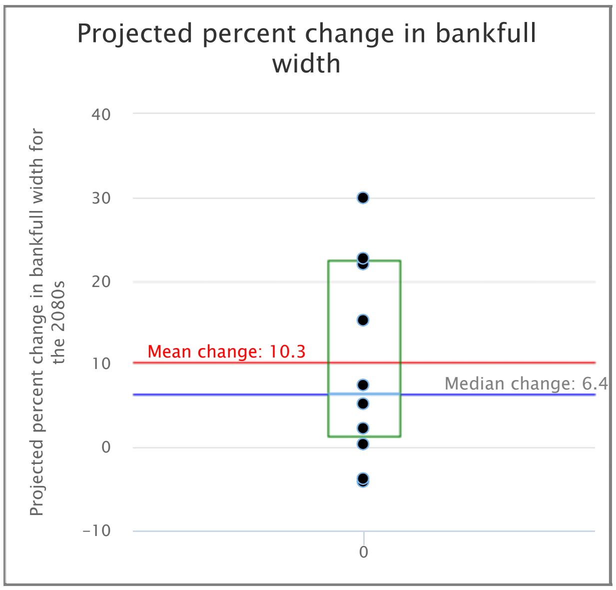
2040s: 7.2%

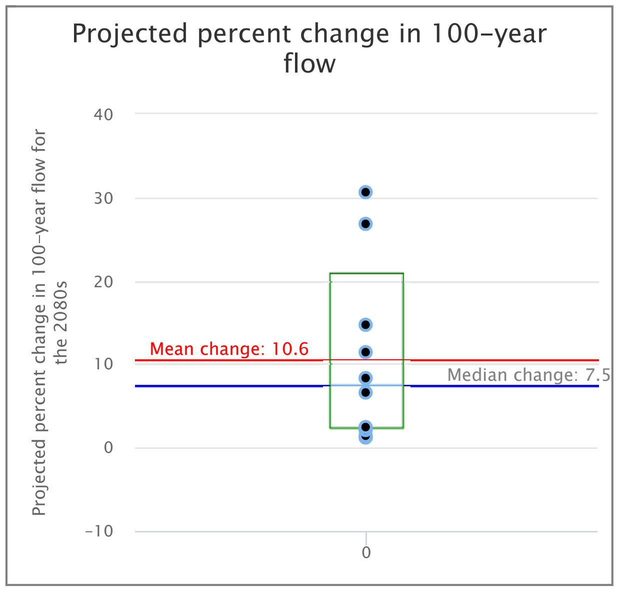
2080s: 10.3%

Projected mean percent change in 100-year flood:

2040s: 3.9%

2080s: 10.6%





Black dots are projections from 10 separate models

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